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Highlights Report, 1993

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Introduction

The Denver Wildlife Research Center (DWRC), the research facility of the Animal and Plant Health Inspection Service's (APHIS) Animal Damage Control (ADC) program, continued to make advances in many areas of wildlife damage management during fiscal year (FY) 1993. Although reregistration and registration of pesticides remained a high priority to the overall ADC program, alternative research efforts increased, and the Center undertook some new initiatives. DWRC scientists continued research into wildlife immunocontraception and resolving bird pest problems to row and fruit crops, aviation, and aquaculture, and mammal damage problems to livestock and timber production. In addition, Center scientists began new initiatives in rangeland rodents, bird repellants and dispersal methods, and mammal attractants.

DWRC continued to strengthen its current cooperative ties with universities and began to plan a major initiative to establish a more comprehensive, cooperative wildlife-damage research system at universities to better address vertebrate pest management needs within the United States.

DWRC also broke ground in September 1993 for a new research facility on the campus of Colorado State University in Fort Collins, CO. These 1993 research and program activities clearly demonstrate DWRC's commitments to the present and future needs of wildlife damage management.

Agricultural Crops

Bird-Exclusion Netting for Commercial Vineyards—Few control measures are available for reducing bird damage in vineyards. The expectation of extensive damage in vineyards with high-value grapes may warrant the implementation of moderately costly protection measures such as protective netting. DWRC personnel developed two types of tractor-mounted, hydraulically powered units for applying and removing bird-exclusion netting from grapevines. The netting system provided cost-effective protection where high levels of damage (>6 percent on yields of 6,804 kg/ha) were anticipated but may not be practical in small vineyards or where low levels of damage are expected. Controlled experiments are needed to quantify the effectiveness of this netting system. Vegetative growth after the onset of grape ripening and the resulting entanglement of vine shoots in the netting may preclude cost-effective use of bird-protective netting with vigorous varieties (e.g., Cabernet Sauvignon) growing on rich soils. Entanglement in nets is a potential source of bird mortality.

Reducing Blackbird Damage to Sunflower in the Northern Great Plains—In Minnesota, North Dakota, and South Dakota, millions of common grackles and red-winged and yellow-headed blackbirds begin congregating in dense cattail marshes in midsummer and concurrently initiate feeding on early ripening sunflowers. Annual sunflower losses to blackbirds amount to millions of dollars. Chemical repellants, mechanical scare devices, avicides, and altered cultural practices have been tested to reduce these losses. Each was found to have limitations because of excessive cost in relation to benefits, logistical considerations, limited effectiveness, or adverse environmental effects. Hence, new management techniques are needed for reducing blackbird damage to sunflowers.

Currently, scientists from DWRC's North Dakota field station, in cooperation with North Dakota State University, North Dakota ADC, and the U.S. Department of the Interior's (USDI) Fish and Wildlife Service (FWS), are testing a new method of lessening blackbird damage to sunflower. The process involves dispersing blackbirds by reducing their preferred roosting habitat in cattail marshes. To accomplish this task efficiently, the aquatic herbicide glyphosate (Rodeo®) is applied aerially to the cattails from a fixed-wing aircraft.

Research on the amount of habitat that must be altered to disperse blackbirds was completed in 1993. The benefits of fragmenting wetlands for other birds, especially waterfowl, were assessed. Data collection on the effects of cattail management on aquatic invertebrates, an essential food source for waterfowl, was completed. Additionally, the first year of a 3-year study designed to assess the effects of cattail management on ring-necked pheasant populations was completed.

Preliminary analyses of the data indicate that herbicide reduction of cattails leads to increased use of treated marshes by waterfowl while invertebrate populations either remain stable or are enhanced by the treatments. The numbers of roosting blackbirds using the treated marshes appear to be significantly reduced. Sunflower damage data will be analyzed to quantify the effectiveness of cattail management for reducing sunflower damage. Experiments begun in 1990 on the effect of various herbicide application rates and timing of sprays on cattails were continued in 1993. Preliminary data indicate that glyphosate applied once at 2 to 2.25 quarts/acre may provide sufficient cattail control at a manageable cost.

Field Testing of Potential Bird Repellants on Fruit—In Florida, researchers evaluated the effectiveness of two potential repellants for reducing bird damage to blueberries. First, a half-acre plot was sprayed with phosmet (Imidan®), an insecticide registered for use on blueberries, according to instructions on the product label. Then, for 10 days afterwards, field crews counted the number of berries on tagged branches in the treatment plot and in a comparable control plot. Results showed that phosmet had little effect on bird-caused damage: losses in the control plot averaged 71 percent compared to 66 percent in the treated plot.

In a second trial, methyl anthranilate (MA) (formulated as ReJeX-iT® AG-36, PMC Specialties Group, Cincinnati, OH) was applied to a half-acre of blueberries at about 24 lb/acre. When captive cedar waxwings were offered berries sprayed with MA and an equal number of unsprayed berries, they consumed 87 percent of the untreated berries and 73 percent of the MA-treated berries. Rapid degradation through microbial activity was probably at least partially responsible for the ineffectiveness of the MA treatment.

Altering Sugar Composition To Control Fruit-Eating Birds—Recent discoveries regarding bird feeding behaviors and digestive physiology suggest that conditioned aversions may develop in response to fruit chemistry. Major fruit-eating pests (e.g., European starlings and American robins) cannot digest sucrose, a minor component of blueberries, cherries, and other small fruits, because these birds do not have sucrase, the necessary digestive enzyme that splits the sucrose molecule. Developing techniques that would substitute sucrose for the simpler, digestible sugars naturally more prevalent in fruit (glucose and fructose) could reduce bird damage. This avenue was explored on two fronts in 1993: biochemical alterations of fruit chemistry and repellancy investigations.

Feeding trials were conducted to evaluate the responses of avian fruit pests with and without the ability to digest sucrose. Cedar waxwings can digest sucrose but do so inefficiently. Starlings cannot digest sucrose. Both species are major fruit-crop pests throughout the country. Researchers at DWRC's Florida field station presented captive waxwings and starlings with artificial fruit made of agar, water, sugar, and food coloring. Both species were able to distinguish between berries containing sucrose and those made with the fructose and glucose. When only fruits containing sucrose were offered, however, interspecific differences were apparent. To compensate for digestive inefficiency, waxwings increased their consumption of artificial berries. In contrast, consumption by starlings dropped to near zero because of postingestional distress. These results suggest that development of high-sucrose cultivars may be useful in the integrated management of some fruit-eating species but not others.

Potential Use of New Insecticide To Reduce Bird Damage to Seeded Rice—In a series of cage tests and flight-pen trials, researchers at the Florida field station evaluated the responses of male red-winged blackbirds to rice seed treated with imidacloprid, a newly developed systemic insecticide. In two-cup tests, when both the treated and untreated seed was either dyed or undyed, individually caged redwings consistently avoided rice seed treated with imidacloprid at 833 and 2,500 p/m. Consumption of imidacloprid-treated seed at 278 p/m did not differ from that of untreated rice. When birds had a choice between undyed, untreated rice and dyed, imidacloprid-treated rice, consumption of treated seed was suppressed at all levels. In a two-cup trial, rice consumption during the 4-day treatment phase was reduced relative to that during the 4-day pretreatment period in the 833 and 2,500 p/m groups but not at 0 and 278 p/m.

During 4-day trials in a 0.2-ha flight pen, 6 different 10-bird flocks removed an average of 41 percent of the untreated rice seed on sample quadrats compared to 9 percent lost from plots having 2,500 p/m imidacloprid-treated seed. Low mean temperatures as well as the presence of avian predators outside the flight pen appeared to increase the birds' consumption of treated rice in some of the flight-pen trials. Feeding rates were reduced in treated plots compared to those in control plots, but the redwings displayed no adverse effects. Researchers estimated that redwings ingested 13–16 percent of the imidacloprid initially present on the seed. Thus, even at 2,500 p/m, red-winged blackbirds feeding normally acquired only a fraction of the imidacloprid calculated to be a lethal dose.

Methyl Anthranilate as a Bird-Repellent Rice Seed Treatment—In a series of two-cup feeding trials, red-winged blackbirds were given rice seed treated with MA (formulated as ReJeX-iT AG-36) at rates of 0, 0.1, 0.5, 1, and 2.5 percent by weight. When the birds' alternate food was untreated rice seed, repellancy was evident at the 0.5-percent treatment rate. When the birds received a commercial bird chow as the alternate food, repellancy was obtained at the 2.5-percent treatment rate. Thus, the type of alternative food can drastically affect expressions of a repellent effect.

In controlled small-plot field evaluations in Louisiana and Texas, researchers tested red-winged blackbird responses to rice seed treated with MA at rates of 0.7, 1.7, and 6.7 percent by weight. Results indicated a deterrent effect at the two higher levels but not at 0.7 percent. The repellent effect persisted for about 1 week after seeding. Improvements in the formulation to retard degradation and lengthen the period of MA activity on the seed should make this a more effective bird deterrent.

Methyl Anthranilate as a Bird Repellant on Ripening Rice—Researchers from the Florida field station conducted a small-plot field test in Vermillion Parish, LA, to evaluate MA (formulated as ReJeX-iT) as a potential deterrent to blackbirds feeding on ripening rice. Four treatment groups of 10 plots each were used. Treatments were single MA applications of 16 and 32 kg/ha and a double application (1 week apart) of 16 kg/ha each. One group of plots served as an unsprayed control. Bird activity on the plots was monitored daily for 3 weeks, and yields from the plots were compared to evaluate treatment effectiveness. Although bird activity in the unsprayed plots tended to exceed that in the sprayed plots, yield data indicated that the treatments had no effect. Additional evaluations employing larger test plots should permit more definitive evaluation of this use of MA.

Chemical Repellants—DWRC scientists based at the Monell Chemical Senses Center in Philadelphia, PA, continue to collaborate with PMC Specialties Group and with other DWRC field stations to develop MA as a practical bird repellant. During 1993, progress was made toward the development and registration of a turf formulation (to repel grazing geese) and a rice seed treatment (to repel blackbirds). In addition, MA was successfully added to a granular pesticide formulation to reduce nontarget hazards that the pesticide presents to birds.

Besides MA, a variety of other repellent materials were identified and tested (e.g., turpentine, activated charcoal). A patent describing the use of activated charcoal as a bird repellant was submitted to the APHIS patent committee.

DWRC-Monell scientists also collaborated with other Monell scientists, University of Pennsylvania faculty members, and DWRC personnel to develop and test new, nonlethal rodent and deer repellants. The data indicate that any substance containing sulfur may repel herbivores (and, incidentally, attract carnivores). Also, experiments suggest that acetophenone derivatives that repel birds may repel rodents as well.

Visual Repellants—DWRC-Monell scientists evaluated the relative effectiveness of white flags, black flags, and Mylar™ streamers as snow-goose grazing deterrents. The results showed that white or black flags diminish grazing. Mylar streamers were no more repellent that bare stakes in control fields.

Reducing Great-Tailed Grackle Damage to Citrus—In recent years, increased great-tailed grackle populations and decreased citrus production inflicted by freeze damage have combined to cause locally severe damage to citrus by grackles in the lower Rio Grande Valley of Texas. In 1987, grackle damage to grapefruit alone was estimated to exceed $2.2 million. Grackles appear responsible for most of the damage that occurs to immature fruit in the spring and ripening fruit in the fall and winter. Resident birds and their offspring cause most of the damage that occurs in the late summer from July through September.

Although grackle frightening techniques appear effective for reducing citrus damage during the fall and winter, no cost-effective methods are available for reducing the bulk of the damage that occurs in late summer. In cooperation with Texas Citrus Mutual and Texas ADC, DWRC scientists are investigating population management strategies to reduce localized summer resident populations responsible for damage. Initial investigations have focused primarily on the use of large (8-x8-x5-ft) walk-in live traps that could be used to remove grackle populations humanely without affecting nontarget wildlife.

Four walk-in trap designs including the modified Australian crow trap (MAC), a modified blackbird decoy trap, a bob trap, and a ground entrance funnel trap designed by DWRC and Texas ADC were initially compared in field trials in South Texas. In the initial trial comparing MAC, decoy, and bob traps, the bob trap was found to be ineffective and was replaced with the funnel entrance trap. In two additional trials, the funnel entrance trap captured between 1.6 and 8.4 grackles per trapping day, which was more than 5 times the trapping rate of either the MAC or decoy trap. The funnel trap was later evaluated in the summer for reducing grackle damage to citrus in South Texas. Grackles utilizing citrus groves were not readily attracted to these traps positioned outside groves: only 24 and 16 grackles were caught in 2 groves, respectively, during 1 month of trapping. At two other groves receiving less grackle use, trap capture rate was zero over the same period. Further research is now proposed to investigate ways of enhancing trapping success at citrus groves and to examine alternative means of reducing localized grackle populations associated with citrus damage.

Evaluation of Bait Markers for Monitoring Consumption by Wild Rats—The most commonly used method for applying rodenticides in macadamia orchards may not be effective for reducing rat populations in some orchards. Growers typically broadcast toxic baits on the orchard floor. However, recent trapping and telemetry studies have indicated that rats spend little time on the surface of the ground; most spend their days in burrows and their nights in the tree canopy. A better understanding of rodent feeding behavior in orchards could help identify locations most likely to be effective for baiting rats in macadamia orchards.

In order to develop techniques to identify rats that consume bait, DWRC researchers conducted a laboratory study to determine the suitability of three nontoxic markers for monitoring feeding by rats in macadamia orchards. A marker was mixed with nontoxic food and placed in various locations in orchards to determine where rats are most likely to find and consume bait. The markers were metallic flake particles that line the gastrointestinal tract, a fat-soluble dye that marks subcutaneous fat, and an antibiotic that stains growing bones and teeth. Each marker was added to nontoxic baits and fed to captive rats, which were examined at various intervals after the trial for evidence of feeding. The antibiotic was the most persistent of the markers and was selected for use in a field study to compare consumption by rats of food placed in trees, on the ground, or in burrows. The results should indicate the most effective location for placing rodenticide baits in macadamia orchards.

Fecundity and Diet of Roof Rats in a Macadamia Orchard—Roof rats were snap-trapped in a macadamia orchard for two crop seasons to determine seasonal changes in fecundity and diet. Captures included 903 males, 756 females, and 16 rats of unidentified sex; males outnumbered females during all months of the study. Immature and subadult rats were present in the orchard throughout the study and comprised 31 percent of captures. The monthly percentage of adult females that were pregnant averaged 19 and varied from about 8 in June to almost 54 in April. A monthly average of 3.9 embryos was detected per pregnant female. Fragments of macadamia nuts were present in all 199 stomachs inspected and on average represented 85 percent of the stomach contents (mean relative frequency). Insect fragments occurred in almost two-thirds of the stomachs, with a mean relative frequency of 8 percent. Lepidopteran larvae were the most commonly identified insect matter. Moss was found in 48 percent of the stomachs, with a mean relative frequency of 4 percent. Grass seeds, fruit seeds, and noninsect animal material were present in small amounts. These results suggest that growers may need to apply control measures throughout the crop cycle to keep rat damage at acceptable levels.

Effects of Trapping on Rat Populations and Subsequent Damage and Yields of Macadamia Nuts—The effects of snap trapping on rat populations in a Hawaiian macadamia orchard and subsequent damage and yields of nuts were evaluated during two cycles. During the first cycle, 1,681 roof rats, 22 Polynesian rats, and 1 Norway rat were captured; 360 rats of undetermined species were captured during the second crop cycle. Cumulative rat damage for the entire season varied from 0.4 to 1.3 percent of total annual production in the trapped sections, and from 1.7 to 3.6 percent of total annual production in the control sections. However, trapping had no effect on yields: number of nuts, mass per nut, and total mass of undamaged nuts did not differ between the trapped and control sections. The results suggest the need to examine crop yield more closely in assessing methods for managing rodent infestations in macadamia orchards. The commonly used indices based on rodent activity and proportion of nuts damaged may overestimate the impact of rodent depredations and exaggerate the effectiveness of control measures in macadamia orchards. A large incidental take of birds points to the need for more selective techniques before trapping is utilized as a damage control measure in Hawaiian macadamia orchards.

Protection of Western Redcedar—Western redcedar is a major commercial tree species of the Pacific Northwest utilized in construction for its decay-resistant properties and natural beauty as an exterior and interior wood. Unfortunately, its foliage is preferred by deer, elk, mountain beavers, and other animals. In making their tree-planting decisions, foresters have long known that animal damage is a significant potential problem with western redcedar and have planted little of it as a result. Now, with major supplies of mature western redcedar inaccessible in national forests because of the need to protect endangered wildlife, replanting this species on other sites has become a primary forestry goal for providing products, creating forest diversity, using a root-rot-resistant species where Douglas-fir cannot establish, and protecting riparian zones for anadromous fish.

DWRC's Olympia field station began cooperative studies with the U.S. Department of Agriculture's (USDA) Forest Service and MacFarlane–Smith, Inc. (Scotland) to examine potential foliar and systemic repellants to protect western redcedar and determine the growth and damage periods when protection is needed in the Pacific Northwest. Initial results on the Gifford Pinchot National Forest have shown damage during the fall and winter by deer and elk with partial protection being provided mainly by application of powdered starling experimental repellant and a registered powdered-egg repellant (BGR®). An experimental coyote urine formulation provided some protection. In some trials, the addition of treated flagging suspended over previously heavily browsed tree seedlings enhanced redcedar protection.

Evaluation of Candidate Systemic Repellent Formulations To Protect Conifers—Pen and field trials were conducted in Washington and Oregon in cooperation with USDA's Forest Service, MacFarlane–Smith, Inc., and the Monell Chemical Senses Center to evaluate formulations of denatonium benzoate as a systemic repellant for conifers. This material is used primarily as a bittering agent to safeguard household products but has shown some promise in Canada, Great Britain, and Scandinavian countries as a systemic animal repellant.

In a variety of trials by DWRC field station staff, denatonium benzoate has been found to translocate into Douglas-fir and western redcedar foliage from root-zone applications. Initial field and pen trials showed high variability in uptake of denatonium benzoate in composite foliage sample collections taken at the time tree seedlings were offered to animals.

Bitter products are not necessarily repellent to wildlife. Penned deer, for example, strongly preferred benzoate-treated western redcedar over treated Douglas-fir. They ate all the offered redcedar in 1 night but took a whole month to consume the same amount of Douglas-fir seedlings. Mountain beaver showed a similar preference for western redcedar.

Translocation of the tableted denatonium benzoate into ponderosa pine and Douglas-fir seedlings in pocket-gopher field tests was not detectable, and all tree seedlings surviving drought conditions were killed by pocket gophers.

At the translocation levels achieved so far, denatonium benzoate has not damaged the plant species tested, but further trials to obtain higher uptake will require examination for phytotoxicity and any corresponding repellancy. Further pen and field trials with deer, elk, mountain beaver, and pocket gophers are needed along with controlled greenhouse or growth-chamber tests using forest soils.

Alternative Damage Control Methods for Pocket Gophers—A number of studies were conducted at DWRC's former field station in Bend, OR, on nonlethal approaches for reducing damage to seedlings by pocket gophers. These studies provided long-term longitudinal data on seedling survival and gopher activity. The alternative methods addressed by these studies include the use of herbicides to reduce preferred gopher food sources, grass planting to reduce gopher food sources, the use of barriers around seedlings, and double stocking seedlings. However, with the closure of the Bend field station in 1984 and the transfer of the study participants to the Alaska Fish and Wildlife Research Center, the large, complex data sets had never been analyzed.

In 1993, DWRC's statisticians had these data sets keybatched and analyzed. Due to the size and complexity of the data sets, the final interpretations remain incomplete, but preliminary results indicate some promising alternatives to lethal control. One study, currently being prepared for scientific publication, compared a control plot with a plot treated with the herbicide atrazine to reduce the forbs and grasses that pocket gophers prefer to eat. Seedling survival, damage rates, and gopher activity were monitored on both plots for 5 years. The atrazine-treated plot showed a substantial reduction in gopher damage rates and greatly increased survival of seedlings.

Control of Mountain Beaver Populations and Precommercial Thinning Affect Douglas-fir Growth—Established Douglas-fir plantations are often stem- and root-girdled by mountain beaver at about the time of canopy closure. Foresters frequently find that the crop trees left after thinning are later killed or injured by mountain beavers. Partially girdled or root-damaged trees are subject to disease and windthrow. Both thinned and unthinned stands may therefore have poorly spaced trees and large, vacant areas caused by mountain beaver damage.

A cooperative study between the Olympia field station and the Washington Department of Natural Resources is investigating the response of tree growth and survival in a large mountain-beaver-occupied Douglas-fir stand about 15 years old. Some sites were initially trapped and others were thinned, and some were both trapped and thinned. Trapping was conducted only before thinning; trapping after thinning is cost prohibitive due to poor access to plots. Measurements were taken yearly on height growth, diameter at breast height, and basal diameters of about 1,000 pairs of damaged and undamaged trees.

Preliminary results after 3 years show statistically significant differences in growth between damaged and undamaged trees. The best Douglas-fir growth rates occurred on units that were trapped or trapped and thinned to 160 stems/acre.

Control of Reinvasion by Mountain Beavers—Reinvasion of existing intact burrow systems by mountain beavers and pocket gophers often cancels any efforts to reduce population densities related to tree damage. Field trials were established about 5 years ago to compare reinvasion in a Douglas-fir plantation that had been heavily populated with mountain beaver before all known animals were removed. Researchers compared 45 burrow systems for rates of reinvasion and occupancy periods. Comparisons were made of activity for 15 systems that had the nest removed, 15 systems that had only the animals removed, and 15 older, inactive systems.

Systems without nests removed were all reoccupied within a few months. Few of the systems with nests removed were consistently reoccupied, and only about 50 percent were ever reused during a 5-year period. Just a few of the older vacant systems were reoccupied.

Plans are being developed to study the removal of mountain beaver nest systems in more sparsely occupied timbered sites prior to logging to determine potential effects on mountain beaver occupancy.

Avoidance of Bird Repellants by Laboratory Mice—Few current candidate avian repellants have been tested against mammals. The efficacy of 1-percent w/v MA, orthoaminoacetophenone (OAP), 2-amino-4', 5'-methoxyacetophenone, 2-methoxyacetophenone, and veratryl amine as mouse repellants was determined in 3-h single-choice drinking tests. Relative to ingestion of plain water, all test substances significantly reduced intake. OAP was the most effective repellant, with intake reduced to levels statistically indistinguishable from zero.

While caution needs to be used when extrapolating from the laboratory to the field, the present results have clear practical implications. For example, one or another of the substances tested in the present experiments might be used as an additive to granular agricultural chemicals to reduce the hazards that these substances present to birds and rodents. In addition, they might be used as rodent- and bird-repellent seed treatments or as livestock feed additives. Both laboratory and field data have indicated that anthranilate derivatives could be effective as bird-repellent feed additives. The possibility that these materials also repel rodents would enhance their utility. DWRC scientists speculate that the tested candidate repellants might also be incorporated into packaging, fabrics, and plastics to prevent damage by gnawing to electrical cables, containers, and other products where repellancy must be instantaneous or where no amount of damage is acceptable. All of these materials appeared offensive to mice at first contact.

Nonlethal Rodent Repellants: Differences in Chemical Structure and Efficacy From Nonlethal Bird Repellants—At least some anthranilates (e.g., MA), and acetophenones (e.g., OAP) are aversive to laboratory mice as well as to birds. DWRC researchers systemically examined nine acetophenone isomers and moieties previously tested as drinking and feeding repellants for starlings. In varying degrees, all nine substances reduced intake by mice in single-bottle tests. Unlike effective avian repellants, the presence of intramolecular hydrogen bonds did not appear to affect avoidance responses in mice.

Maternal Ingestion of a Mouse Repellant During Gestation Affects Subsequent Intake by Offspring—Ingested flavor chemicals cross the placental barrier in mice and occur in the fetal blood and amniotic fluid. This occurrence is detectable by the fetus and can influence feeding after birth. DWRC researchers examined this effect experimentally, using OAP, which mice normally avoid, apparently on the basis of chemosensory characteristics. In one group, pregnant mice were given water containing 0.1-percent OAP, while in another, pregnant mice were given plain water. Subsequently, half the male offspring were offered 0.5-, 0.25-, or 0.1-percent OAP in single- bottle tests at 28 days of age, and similar tests were administered to the other male offspring at 90 days of age. Offspring born to mothers that ingested OAP during pregnancy drank greater amounts of 0.1-percent OAP than did offspring born to mothers that received plain water during gestation. Treatment groups responded similarly when offered OAP at the higher test concentrations. At 90 days of age, there were no significant differences among groups. Adult mice exposed to 0.1-percent OAP for a duration similar to that given during gestation did not ingest more OAP-treated water than did their respective controls.

This experiment demonstrates that prenatal experience with an otherwise aversive flavor can increase ingestion of that flavor after birth. The reason for this increase in intake remains obscure, although the most likely possibility is simple exposure or an enhanced preference as a consequence of pairing with nutrient delivery via the placenta.

Tolerance of Bitter Compounds by a Herbivore—Many plant defensive chemicals taste bitter to humans. Because of this taste characteristic, and because bitter compounds are often toxic, such substances, and the plants that contain them, are regarded as generally unpalatable to wildlife. These assumptions, however, may be unwarranted. To test the hypothesis that herbivores are indifferent to bitter tastants, DWRC scientists investigated the responsiveness of guinea pigs to denatonium benzoate, denatonium saccharide, limonene, L-phenylalanine, naringin, quebracho, quinine, RoPel® (a commercial animal repellant containing denatonium saccharide), and sucrose octaacetate. Only quinine and sucrose octaacetate slightly but significantly reduced feeding. These findings were inconsistent with the notion that herbivores generally avoid what humans describe as bitter tastes.

Selective Criteria for Douglas-fir Damage by Bears—Damage to maturing Douglas-fir trees by bears is an increasing concern for the timber industry. Productive, rapidly growing trees appear more likely to be damaged by bears than less productive trees. Initially, DWRC scientists hypothesized that this phenomenon may reflect a more nutritious sapwood (increased sugar content) in the rapidly growing trees or more concentrated chemical defenses in the less productive trees. Captive bears in two-choice tests, however, did not differentiate between sapwood collected from fast-growing trees and sapwood collected from slower growing trees of the same age. This result suggests that the preference of productive trees by bears may simply reflect the energetics of collecting available material. Sapwood on trees located in dense canopies is less abundant and more difficult to harvest than sapwood on trees found in open canopies.

Nuisance, Safety, and Health Concerns

Reducing Bird Hazards to Aircraft—Collisions between birds and aircraft cost the air transport industry and the military many millions of dollars annually and pose a significant threat to human safety. DWRC biologists, with funding provided under interagency and cooperative agreements with the Federal Aviation Administration (FAA), the U.S. Air Force, and the Port Authority of New York and New Jersey, are pursuing several areas of research to reduce the incidence of bird–aircraft collisions.

Landfills located near airports can create hazardous conditions for aircraft because birds, especially gulls and starlings, are attracted to these sites to forage and soar. DWRC biologists are studying bird use at and around various types of landfills (e.g., general, composting, trash transfer stations) to determine the influence that these landfills are having on bird populations and to assist FAA and other regulatory agencies in making decisions about the siting and operation of landfills near airports.

A study in 1993 in Cleveland, OH, documented at least 2,400 gulls of 2 species successfully nesting on a food warehouse rooftop in an industrial park 13 miles from Lake Erie. The study showed that the gulls were able to use this unlikely urban site for nesting because they could easily obtain food from a landfill 3 miles away.

Gulls and other birds are often attracted to airports after heavy rains to drink and bathe in temporary pools of fresh rain water, especially in salt-water coastal areas. Aviary and field trials have shown that MA, a nontoxic chemical used as a human food flavoring, repels birds from water when added in low concentrations. Aviary tests in FY 1993 also showed reduced feeding activity by gulls and cowbirds in pans of food covered with a landfill-cover material treated with MA. Efforts are currently underway to register MA in several formulations as a nontoxic bird repellant for water and for landfill cover materials.

DWRC laboratory and field research has demonstrated the effectiveness and safety of alpha-chloralose (A-C) for capturing nuisance geese, ducks, coots, pigeons, and gulls. From 1988 through 1992, A-C was successfully used in the United States to immobilize and remove more than 2,500 nuisance waterfowl and pigeons from 30 commercial, industrial, agricultural, and residential sites, including golf courses, pools, feedlots, and airports.

DWRC research has shown that A-C can serve as a humane, environmentally safe, and publicly acceptable means of removing certain bird populations from airports and other locations where these birds conflict with human activities, especially since traditional methods of control (e.g., trapping, shooting, poisoning) are becoming more restricted and less acceptable. Based on DWRC research findings, the U.S. Department of Health and Human

Services' Food and Drug Administration issued in 1992 an Investigational New Animal Drug Agreement for A-C use by Federal ADC biologists nationwide for capturing problem birds (waterfowl and pigeons) at airports and other sites. This program became operational in FY 1993 with DWRC biologists providing training and certification for more than 25 ADC biologists. Research in FY 1994 will be directed at adding species of birds (such as gulls and crows) to the label for A-C use.

DWRC biologists completed an analysis for the Port Authority of New York and New Jersey of all air-carrier-reported bird strikes at John F. Kennedy International Airport (JFKIA), 1979–92. During the 14 years, there were 76 arriving or departing aircraft at JFKIA for which the air carriers reported damage or delays caused by bird strikes. Economic losses and safety risks resulted from 43 damaged engines (at least 14 requiring replacement), 21 aircraft with nonengine damage, and 46 aborted takeoffs. Because bird strikes and damage are reported voluntarily by the air carriers to the Port Authority, these data are likely incomplete. For example, these loss and safety-risk estimates do not encompass the 2,428 incidents unreported by air carriers in which 2,552 dead birds (that showed evidence of interacting with aircraft) were found by Port Authority personnel on active runways over the same 14-year period. Although 55 species of birds have been struck by aircraft at JFKIA, 75 percent of the strikes causing damage were by 3 species of gulls.

Biologists from DWRC worked cooperatively with New Jersey ADC personnel from 1991 to 1993 to evaluate the effectiveness and impact of shooting gulls at JFKIA to reduce the incidence of gull–aircraft collisions. This project, funded by the Port Authority of New York and New Jersey, resulted in a 90-percent reduction in such collisions during 1993 compared to the baseline years, 1988–90. Shooting was carried out from late May to early August when thousands of laughing gulls associated with a nearby nesting colony cross runways at JFKIA on their way to and from foraging areas. The long-term plan is to relocate the nesting colony away from the airport.

Laughing-gull populations in the Northeastern United States have increased substantially since the late 1970's. These increasing populations have caused a concurrent increase in conflicts with humans, especially at airports where the gulls pose a hazard to aircraft. DWRC biologists censused the laughing-gull nesting colony in Jamaica Bay, NY, in June 1993. A series of 31 overlapping aerial photographs were taken from 1,200 feet above sea level of 3 marshes totalling 600 acres located adjacent to JFKIA. The photos were enlarged to 36x36 inches, covered with clear plastic, and gridded into 5-acre plots. An observer examined each grid with a magnifying glass and circled all detected nests with permanent marker. In all, 5,300 nests were counted. Observers could detect about 89 percent of the nests on the aerial photographs, based on the number of nests detected in 7 100-x100-foot "ground-truth" plots with known numbers

of nests. Thus, the actual number of nests in the colony was probably around 6,000, representing 12,000 adult birds. This newly developed census technique should greatly assist wildlife managers in the monitoring and management of gull colonies near airports and in other localities where gulls conflict with human activities.

The 3,662 recovery records for laughing gulls banded in North America from 1924 through 1991 were analyzed by DWRC biologists to determine migration and dispersal patterns. About 55 percent of Northeast (Maine to Virginia) laughing gulls wintered in Central and South America. In contrast, 67 percent of laughing gulls that nested on the gulf coast remained there during winter. Laughing gulls displayed high fidelity to their area of natal origin: 64 percent of adults recovered during subsequent breeding seasons were within 50 km of their natal colony. There was little interchange between northeastern and gulf coast adult laughing-gull populations. Information from this study is being used to model laughing-gull population dynamics in relation to gull management at JFKIA and Atlantic City International Airport.

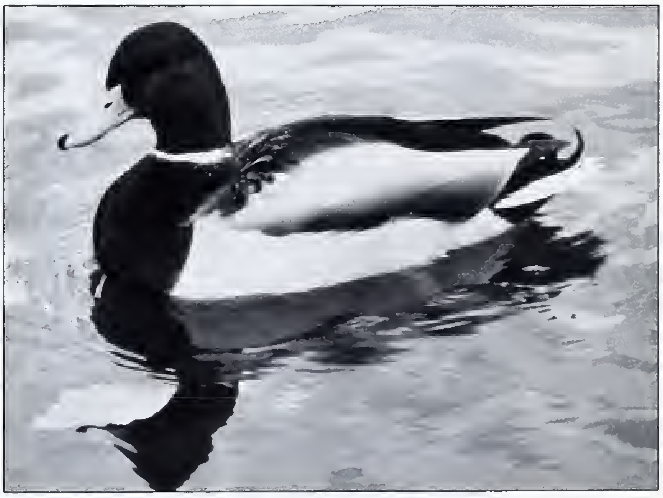
In another field study, a new technique was developed for marking nesting gulls with a colored dye that does not affect the hatchability of eggs. The technique involves putting adhesive tabs covered with dye on the eggs. The dye is transferred to the adult birds when they incubate, but the tabs keep the oil-based dye from the eggs. Previous studies using dye in petrolatum applied directly to the eggs resulted in a high level of egg mortality. Work is now focused on improving the transfer and retention of the dye to the gulls' feathers. Color-marking gulls is an important technique to determine their movement patterns between nesting colonies, landfills, and airports.

More than 80 people attended the third annual meeting of Bird Strike Committee USA (BSCUSA) at SEATAC International Airport, Seattle, WA, August 3–5, 1993. DWRC biologists organized the scientific program in which 23 papers were presented on topics related to the economic and safety problems caused by birds colliding with aircraft. A panel discussion was also held on land use around airports, particularly for landfills and wetlands that attract birds. Attendees included representatives from the air-transport and solid-waste-management industries, airports, natural resource agencies, animal welfare groups, FAA, and the military. The goal of BSCUSA is to increase communication and awareness among the diverse groups dealing with wildlife issues on airports, and the 1993 meeting appeared to be highly successful in this regard.

Phenylethyl Alcohol Tested as Avian Repellant— Phenylethyl alcohol was evaluated as an odor-based avian repellant in 81 starling nest boxes attached to utility poles. Initially, this substance looked promising because 20 days after treatment on April 29, 1993, the 27 nest boxes containing alcohol-impregnated capsules had significantly fewer starling nests with eggs than did 27 untreated nest boxes or 27 boxes with "eye spots" (painted eyes or stickers that are put on nesting boxes as visual repellants). However, by the end of the nesting season in July, there was no significant difference among the three treatments in the number of nest boxes that had fledged young. Overall, 15 of 27 alcohol-treated boxes fledged starlings compared with 20 of 27 eye-spot boxes and 17 of 27 control boxes. Although phenylethyl alcohol at least showed some initial repellancy, the eye spots appeared totally ineffective in reducing nesting by starlings. No additional testing of phenylethyl alcohol is planned.

Reducing the Risk of Waterfowl to White Phosphorus— The U.S. Army has used Eagle River Flats, a 1,000-ha salt marsh at Fort Richardson, AK, since 1945 as an artillery impact area. During the past 10 years, waterfowl, specifically mallards, pintails, and green-winged teal, have been found dead on the Flats during spring and fall migration. Their mortality has been attributed to the ingestion of white phosphorus residue in marsh sediment.

Center biologists conducted a series of tasks directed at reducing waterfowl mortality on Eagle River Flats. The tasks are related to development and evaluation of a waterfowl repellant (MA) as an intermediate remediation action, documenting distribution and movement of waterfowl in the Flats, assessing the secondary hazards of white-phosphorus-exposed ducks scavenged by bald eagles, and conducting preliminary assessments of a sediment covering agent.



In 1993, biologists continued to evaluate new bead formulations of MA in the laboratory and field to determine their effects on waterfowl feeding behavior. New formulations retain MA 7 to 20 times longer than a formulation used in 1992. Evaluation of one MA formulation in a simulated pond setting showed that an application rate of 21.7 kg/ha to pool-bottom sediment significantly decreased use of the pools by mallards. On Eagle River Flats, another MA formulation applied at a rate of 43.4 kg/ha to contaminated sediment reduced the mortality rate of mallards. Mallards in untreated areas were 2.6 times more likely to die from white phosphorus exposure than ducks in areas treated with MA.

To remediate Eagle River Flats, the Army is considering dredging or covering sediment contaminated with white phosphorus. Center scientists evaluated two covering materials, Concover® and Bara-kade®, as a physical barrier between white phosphorus and waterfowl. Concover proved to be unstable under laboratory conditions and was not field tested. A 5-cm layer of Bara-kade prevented all mortality.

During fall migration, August and September, movement data from 40 ducks fitted with radio transmitters indicated that a variety of species used a small portion of the Flats and that ducks segregated by species into certain areas. The rate at which birds moved through the area during this same 60-day period was about 50 percent.

Managing Canada Geese—Populations of Canada geese in U.S. flyways have increased about threefold in the last 10 years. Although these increasing populations are a positive step in the conservation of waterfowl, Canada geese are now frequently implicated in habitat destruction, crop depredation, nuisance problems, and incidents threatening the safe operation of aircraft. One management method widely used is egg addling. However, although several techniques such as shaking, removal, cracking, or puncturing may cause egg failure, geese tend to renest the same season.

In 1993 at Lake Washington, WA, Center scientists investigated the hatching success of Canada goose eggs sprayed with white mineral oil. Seventy-one nests containing 344 eggs were selected for inclusion in the trial. Of those, 201 eggs were sprayed with white mineral oil at a rate of 7 mL/egg. An average clutch was sprayed in less than 10 seconds. Results showed that 18 clutches containing 92 eggs were incubated up to 25 days past their expected hatching date. The remaining treated eggs failed due to predation or environmental factors. These data will be used to support future registration of white mineral oil for Canada goose control.

An Approach to Managing Urban Blackbird Roosts—Large winter roosts of blackbirds and starlings have long been a concern to residents of the Southeastern United States, especially where roosts occur near human habitation. These urban and suburban roosts cause substantial nuisance problems, and when they occur in the same sites over several years, they are associated with possible outbreaks of the fungal respiratory disease histoplasmosis.

Current approaches for alleviating problems with these birds in urban and suburban roosts rely primarily on forced relocation of the birds. This process, which involves either frightening devices or habitat alteration, is often successful in reducing problems but can entail moving birds to an equally undesirable location.

One alternative means of alleviating urban and suburban roost problems is to establish, away from human habitation, roosting habitat sufficiently appealing that it attracts birds away from objectionable sites. Using data from historical winter roost surveys, DWRC scientists examined and compared habitat types reported based on the following criteria: (1) frequency of historical use, (2) history of accommodating high bird densities on a limited area, (3) history of repeated localized use, (4) history of utilization over a wide geographic range, and (5) history of occupation by starlings and all major blackbird species.

This analysis revealed the importance of bamboo and native cane as a widely used habitat by all blackbird species. Bamboo and cane rival all other habitat with respect to traditional site use (up to 30 years), highest roosting densities sustained (up to 6.5 million birds per ha), and the smallest geographic area required to sustain a million birds or more. In light of its limited availability compared with more commonly occurring habitat in woodlands and marshes, the widespread and repeated use of bamboo and native cane suggest that starlings and blackbirds prefer this habitat type for roosting. Comparison of bamboo and cane structure with features associated with preferred roosting structure also revealed the potential ecological attractiveness of bamboo or cane as a candidate for this "lure roost" habitat approach.

As a followup to the previous study, Center scientists gathered information from the literature, as well as from consultations with horticulturists and onsite visits to bamboo plantations to select desirable varieties of bamboo for this purpose and to identify preferred propagating techniques. The chosen bamboo varieties ranked highest in terms of cold tolerance, propensity for lateral spreading, and structural features for maximizing blackbird roosting-population densities. Based on the results of these investigations, future research is now proposed to test the hypothesis that bamboo plantations are sufficiently attractive to shift blackbird roosting away from urban and suburban sites. This research would involve both examining roosting fidelity to existing plantations and developing new roosts in traditional problem areas.

Livestock

Electronic Monitoring of Traps and Snares—Scientists from the mammal research section, working with the electronic engineering support group at DWRC, evaluated the feasibility of using telemetry devices to determine whether traps or snares had been sprung. Prototype devices were manufactured and purchased from wildlife telemetry firms in the United States. These devices were tested in the lab to determine electronic output and then tested in the field to determine range performance. Preliminary field tests in the rolling plains of eastern Colorado suggested that signals from the test devices could be received at distances of greater than 20 miles on the ground and at over 93 miles from the air.

Field studies conducted in cooperation with ADC personnel in California and Oregon confirmed the utility of using this technology in operational programs to resolve wildlife damage complaints. Traps and snares could be monitored in most situations at distances above 10 miles without actually visiting each device. This benefit would allow traplines to be checked more efficiently and more often.

Additional research is needed to increase distance potential, examine portable antenna systems, and develop inexpensive, weatherproof sensors to activate transmitters after a trap has been disturbed by an animal. Important future issues related to use of such technology will be the availability of radio frequencies and acceptance of remote or electronic trap checks by State game agencies.

Development of a Breakaway Snare Lock—Snares are an important tool used by the ADC program for controlling damage caused by coyotes. Concern for reducing the number of captured nontarget animals, such as domestic livestock and deer, led to the development and evaluation of a new breakaway lock. Early research focused on determining the tension loads that animals such as coyotes, deer, cattle, and sheep place on snare locks. Once this information was acquired, it was used to pursue the goal of developing a snare lock that would be effective for capturing coyotes and at the same time release the majority of nontarget species. Because of the high cost of working with engineering firms, cooperative research was initiated with engineering students at the Colorado School of Mines and Colorado State University to help develop prototype designs.

After gaining experience with different types of lock systems, DWRC investigators concluded that the Cam-Loc® system had the greatest potential for developing a breakaway snare that would release consistently at a threshold strength. A metal company in Denver produced a modified camlock that would accommodate a 1/16-inch-diameter shear pin. Pins were constructed from aluminum welding rod with an average breaking strength of 260 pounds.

Prototype shear-pin locks were evaluated in Montana, North and South Dakota, Colorado, and Texas by ADC personnel who normally use snares in managing coyote predation. Results suggest that shear-pin locks can be effective in capturing coyotes while releasing nontarget animals. From May 1992 through March 1993, 104 coyotes were captured using the prototype locks. Of the 104 coyotes, 95 (91 percent) were held and 9 (9 percent) escaped by shearing the pin in the lock. Thirty-five deer were captured; 18 of these animals released themselves by breaking the lock. Sixteen of the 17 deer that were held in the snares were caught by the neck. Researchers believe that most of the released deer were caught by the leg. Six cows or calves were caught in snares; all of these animal successfully released themselves. Further testing is planned to facilitate the manufacture of a lock that will reduce the proportion of coyote escapes.

Developing Strategies for Nonlethal Coyote Control—Predators, primarily coyotes, cause significant losses among domestic livestock and pose a serious economic liability to many agricultural enterprises, especially sheep ranching. Growing public sentiment against the use of lethal methods of control, restrictions on the use of chemical predacides, and today's more stringent requirements associated with maintaining current chemical registrations all point to the need for greater emphasis on developing alternative methods of predator management. In order to do this, researchers need a better understanding of both the circumstances that lead to depredations and the characteristics of those predators most likely to attack sheep.

A cooperative predator research program has recently been established between DWRC and the University of California at Berkeley and the University of California's Hopland Research and Extension Center. The goal is to develop control strategies that incorporate nonlethal methods. Field studies directed at the coyote-sheep problem were initiated during FY 1993 at Hopland in north coastal California, where sheep are kept year-round in pastures, and at the UC-Sagehen Creek field station in the Sierra Nevada, which is summer range for sheep.

The initial phase of research has involved problem description. At Hopland, this includes determining the (1) annual pattern of predation from historical records, (2) day-to-day pattern of predation by individual coyotes, (3) movements of coyotes in relation to the daily foraging and resting patterns of sheep, and (4) timing and location of predation relative to bedding and midday resting of sheep.

Preliminary findings suggest that at least some coyotes track sheep closely during the day, even in the presence of a guard dog, and that tracking can occur on and off for weeks without sheep kills. These findings suggest that coyotes may be very wary of opportunities for predation, especially where control efforts have been intensive. Daytime tracking may explain why, in some cases, guarding animals such as donkeys or llamas are effective despite being diurnal and therefore unlikely to intervene during nocturnal predation. Tracking also explains how guarding animals or frightening devices can lose their effectiveness as coyotes have the opportunity to observe them and either to habituate to their presence or prey upon sheep after they have dispersed from a bedding or nooning site and are scattered and difficult to guard. At Sagehen, radio-collared coyotes did not seem to be attracted to sheep for the 3 weeks that they were moving through the Sagehen Basin in late summer. No coyote kills occurred, supporting the Hopland observation that coyotes may be cautious about approaching new and potentially dangerous situations.

Aquaculture

Censusing Great Blue Heron Populations at Catfish Farms—Depredations by the great blue heron are of concern to Mississippi catfish growers, but the economic impact of these depredations is still unclear. Census data on heron populations are needed to help determine this impact. As part of a 3-year study of the effect of great blue heron depredations on the catfish industry, DWRC scientists have completed a census of great blue populations on 19 randomly selected catfish complexes in the Mississippi Delta. Complexwide counts of herons were taken every 3 hours on days when diurnal observations of heron feeding activities were made. Heron densities varied from 0.03 to 1.04 birds per water-hectare and averaged 0.22 heron per ha. This density is remarkably similar to that reported for grey herons, a closely related European species, on Belgian and Dutch fish farms. If this density holds for the more than 41,000 water-hectares of catfish farms in the Delta, it would mean the catfish industry there is supporting a population of roughly 9,000 great blue herons. Thus, the average catfish farm in the Delta containing 126.7 water-hectares would support a year-round population of 28 great blue herons.

Trends in Wintering Cormorant Populations Associated With Catfish Production—Historically, double-crested cormorant populations from the Great Lakes and central Canada have migrated down the Mississippi River to winter along the shores of the lower Mississippi and Gulf of Mexico. However, October-December wintering populations along the lower Mississippi were reported to be very small. Following construction of the first commercial catfish pond in 1965, the catfish industry in the lower Mississippi Delta region grew rapidly during the 1970's and 1980's and presently exceeds 40,500 ha. Concurrent with the growth of the Mississippi catfish industry, breeding cormorant populations in the Great Lakes and Canada began to increase dramatically in the mid 1970's and 1980's, as a result of reduced persecution and pesticide levels. Christmas Bird Count data on wintering cormorant populations from one location in the Mississippi Delta indicated similar drastic increases from 1981 to 1988. In 1988, cormorant populations in the delta peaked at 3,410, and ADC biologists estimated the total population in the delta at approximately 50,000 birds.

Since 1989, DWRC biologists in cooperation with Mississippi ADC have been monitoring wintering cormorant populations in the delta region by counting birds as they leave or enter their night roost sites. These sites located in cypress swamp habitat are distributed throughout the 16,000-km^2 delta region but are clustered primarily along the Mississippi River and in that part of central Mississippi with the highest catfish production. Although only 12 sites were known in 1989, 19 additional sites have been located from tracking transmitter-equipped cormorants and more recently from systematic aerial surveys of these wetlands in the delta. Since only about half of these sites are active at any one time, the present aerial survey methodology provides a way to locate active sites for censusing. Despite the increase in roosting sites identified, peak cormorant populations over the past 4 years have remained fairly stable at approximately 30,000 birds.

Evaluating the Use of Mannequins and Look-Alike Replacement Shooters To Reduce Predation by Cormorants and Wading Birds—Catfish growers have been reluctant to use the Scarey Man device that has been found effective in helping repel cormorants from catfish ponds at least in part because of its cost ($600 each). Therefore, inexpensively constructed (less than $50) yet realistic mannequins, reinforced when needed by shooters dressed to resemble the mannequins, were tested for efficacy in repelling cormorants from catfish ponds in the Mississippi Delta. No other means of crop protection was provided during the test.

On two pairs of test complexes, the average numbers of cormorants flushed per census trip on the treated complexes decreased from 244 and 216, respectively, during 5 days of pretreatment counts to 27 and 4 cormorants flushed per census trip, respectively, for the 10 days the mannequin-and-shooter regime was in place. These decreases averaged 89 and 98 percent, respectively. In contrast, decreases over the same time periods for the control ponds were 24 and 0 percent.

Twenty-four mannequins were used to provide protection to 20 ponds. A shooter dressed to resemble the mannequins replaced them for an average of 1.1 hours per pond where cormorant habituation was beginning to occur. However, 92 percent of the shooter's time was spent at four ponds with shad populations, which tend to be especially attractive to cormorants. The shooter fired an average of 7.6 shotgun shells or pyrotechnics per hour. This combination of mannequins and shooters dressed to resemble the mannequins showed promise as an effective means of repelling cormorants during this comparatively short test.

Recently, Audubon Magazine drew national attention to the destruction of depredating egrets and herons at Arkansas baitfish farms. In an attempt to develop an effective nonlethal technique to repel these birds, a novel scaring program was deployed in August 1993 at two of these farms. The program involved the deployment on the ponds of the inexpensive yet realistic mannequins that could be readily replaced by an individual dressed to closely resemble them whenever bird habituation to the effigies began to occur. Twelve mannequins were deployed over 13 ponds at an average rate of 1 mannequin per 6.2 ha. The individual shifted from mannequin to mannequin in attempts to confuse the birds as to whether the mannequins were actually shooters or not. Except for a brief period when the mannequins were first deployed, they were not effective in repelling egrets and herons unless the shooter was physically present in place of one of the mannequins. Additional shooter effort might have been efficacious but was considered to be economically unrealistic.

Dispersing Cormorants From Roost Sites—Double-crested cormorant populations wintering in the lower Mississippi valley have come into serious conflict with an expanding fish farming industry. The dollar value of bird-caused losses to catfish producers in the area has been estimated at \$2 million to \$3 million. Most often, attempts to reduce cormorant predation involve the use of bird scaring devices at the damage site. But these efforts often have only short-term effectiveness because the birds habituate to the devices over time.

Dispersing cormorants from nighttime roost sites is a possible alternative to reducing predation at catfish ponds and may have more longlasting effects. Initial roost-dispersal investigations in 1989 demonstrated that cormorants at a single roost could be easily relocated with the use of pyrotechnic devices and that cormorant foraging activity in the area surrounding the roost site was also reduced. A 1993 study was designed to evaluate the effectiveness of dispersing all cormorants in a multiroost area in an attempt to keep the area free of all cormorant roosting activity. During this study, between 89 and 3,032 pyrotechnic devices (mostly pistol-fired Screamer Sirens™) were used to disperse each roost containing from 200 to 14,000 cormorants.

In all, six roosts within a three-county area were dispersed and kept free of cormorant activity from January through the end of the roost season in early April. Cormorant roosting populations in the treated area were reduced from about 18,000 birds to zero during the course of the study. Between one and seven people were used to disperse each roost with the pyrotechnic devices in the course of only a few evenings of dispersal effort. The technique involved firing pyrotechnics at cormorants arriving at the roost during an approximate 2-hour period just before sundown. Although the roosts could be dispersed in a short period, it was necessary to station a person at the site on succeeding evenings during the study to prevent the birds from returning. Concurrently, cormorants in an adjacent untreated 3-county reference area increased from about 7,000 to 20,000 birds during this same time period. During the study, roosting sites also increased from two to four in the untreated area.

Based on these positive results, an additional study to evaluate this procedure for reducing cormorant damage throughout the entire 15-county catfish production area in the Mississippi Delta has been proposed.

Cormorant Movements in Response to Roost Dispersal—During the winter of 1992–93, 28 double-crested cormorants were captured and fitted with radio-telemetry transmitters in the Mississippi Delta region. In all, 25 cormorants were monitored to determine roost fidelity and movements in response to coordinated roost-dispersal efforts. Transmitter-equipped cormorants used 15 different roost sites during the study. Of 14 cormorants in control roosts, 7 changed roosts after transmitter attachment, whereas all 11 cormorants in treated roosts changed roosts. There were no significant differences in cormorant movement among roosts between treated and control areas after transmitter attachment. Of the 14 cormorants in control roosts, 3 (21 percent) changed roosts more than once; of the 11 cormorants in treated roosts, 5 (45 percent) changed roosts more than once.

The distances moved by cormorants in treated and control roosts ranged from 16 to 390 km and from 0 to 398 km, respectively. There were no significant differences in distances moved by cormorants between treated and control roosts. Three transmitter-equipped cormorants were located on the gulf coast approximately 390 km from the study area. One was later relocated in the study area. During this study no transmitter-equipped cormorants attempted to reenter a treated roost after the third night of dispersal efforts.

The widespread roost movements throughout the Delta and the locating of three transmitter-equipped cormorants on the gulf coast provide evidence that these wintering cormorant populations may be nomadic. As with other communal roosting birds, cormorants that winter in Mississippi show no strong fidelity to a primary roost and are most likely moving throughout the Delta and the gulf coast. These telemetry data suggest that limited roost dispersal efforts seem to have no long-term effects on movements of cormorants.

Product Development

Forward-Looking Infrared Technology—Wildlife managers and researchers have developed many useful methods for censusing wildlife, including visual counts and photography from aircraft. New methods and technologies aim at improving accuracy and increasing the size of areas being surveyed. One of the technologies being tested for application to wildlife management is forward-looking infrared (FLIR) imagery. Researchers have had reasonably good success in testing airborne FLIR imaging devices for locating and identifying ungulates, primarily deer. DWRC's current study to determine if FLIR can be used to identify and census coyotes is the first of its kind.

APHIS' ADC program has a growing need for census data on coyotes and other small wildlife species, over large areas, to determine the effectiveness of operational and research activities. Recently, a cooperative study between DWRC and ADC's Western Region was initiated to determine the feasibility of using airborne FLIR technology (i.e., thermography) for censusing coyotes. The first phase of the study consisted of a series of transect-oriented flights over a known number of coyotes confined in cages and outdoor enclosures at the DWRC Predator Research Facility near Logan, UT. Other species included in the test were caged foxes from a local fur farm, deer, bison, and domestic livestock. Several flight parameters, including various altitudes, camera angles, and camera fields-of-view, were incorporated into the study to help determine the most effective approach for the positive identification of target animals. Thermal imagery was generated by a FLIR Systems, Inc., Model 2000 AB thermal imager aboard a Cessna 210 aircraft.

Analysis of the thermal data by a computer-enhancement program showed that thermal images of the animals were evident, but positive identification by species was inconclusive. Researchers concluded that, while the concept of using FLIR technology as a transect censusing tool is valid, another available imager (with higher spatial resolution) may make positive species identification possible. The data analysis also suggested that a proper combination of certain flight parameters used in the study, in addition to a precise aircraft guidance system, may provide optimum conditions to positively identify target species in imagery generated in a flight transect mode.

The next phase of this study will be to evaluate a higher resolution imager operated under optimal flight parameters.

Electrofishing—DWRC engineer Lawrence Kolz' 1993 publication "In-water Electrical Measurements for Evaluating Electrofishing Systems" is an example of how research originally intended to support one biological technology can be applied and transferred to another. That publication described the electrical fields generated in a volume of water by various electrode configurations, and the data were published to assist fishery biologists in the proper usage and adjustment of electrofishing equipment. However, in-water electroshocking techniques have now been conceived as a possible method of control in localized areas for aquatic mammals and birds, including beaver, nutria, muskrat, ducks, and geese. Kolz observed that the measurements published for electrofishing applications are now readily adapted for electroshocking research with aquatic animals.

DWRC staff have demonstrated the repellent effects of in-water electroshock on beavers by conducting a pilot study where they were successfully repelled from a damage site with nonlethal, electroshocking apparatus. Beavers were unable to repair a breached dam while the electroshocking devices were operational. However, the beavers repaired the dam every night that the devices were purposely shut off. This new methodology will be studied in more detail in 1994.

Product Chemistry

Pesticide Reregistration: Halfway There—The reregistration of ADC pesticides began in 1989 and should be completed by 1997. During FY 1993, 27 studies costing more than $850,000 were completed and submitted to the Environmental Protection Agency (EPA) or are in progress at DWRC or by contractors. Negotiation of all remaining reregistration data requirements for DRC-1339 have been completed. For strychnine, the status of 7 studies remains to be resolved with EPA, and for zinc phosphide, 12 studies need to be resolved. Reregistration of the active ingredients in the gas cartridge was completed in FY 1993, and 18 studies were completed by DWRC and submitted to EPA to support the new gas cartridge for rodents. Following negotiation with EPA, the estimated cost of obtaining required data on Compound 1080 and sodium cyanide was reduced by an additional $800,000. Five studies were begun to complete Compound 1080 reregistration.

Two 12-day acute dietary LC_{50} studies to assess DRC-1339's effects in mallard ducklings and young bobwhite quail were submitted to EPA. The research was part of the reregistration agreement for Starlicide® technical, and data were submitted by DWRC on behalf of Purina Mills, Inc. Bioassays and diet analyses were performed by private-sector contractors. The LC_{50} values (95-percent confidence limits) were 322.0 (232.8–432.7) p/m for mallard ducklings and 14.1 (8.8–21.0) p/m for young bobwhite quail.

Pesticide Registration: Progress—Registration activities for ADC pesticides accelerated during FY 1993 and were focused on seven major areas: (1) amending the Livestock Protection Collar (LPC) registration to include the large collar, (2) obtaining a new consolidated registration for Compound DRC-1339 98 percent Concentrate—Livestock Depredations, (3) amending the rodent gas cartridge registration to contain only two active ingredients, (4) resolving a number of registration issues for zinc phosphide technical and end-use products, (5) resolving registration issues for strychnine technical and end-use products and meeting the requirements of the Strychnine Settlement Agreement, (6) obtaining a new consolidated registration for Compound DRC-1339 98 percent Concentrate—Staging Areas, and (7) conducting laboratory studies with Compound DRC-1339 98 percent Concentrate—Pigeons that were required by EPA. The LPC registration and the DRC-1339—Livestock Depredation actions were approved by EPA, a summary of the DRC-1339 laboratory studies was submitted to EPA, and the new gas cartridge and DRC-1339—Staging Area registration activities are proceeding toward closure in FY 1994. Strychnine and zinc phosphide issues are also approaching resolution.

DRC-1339 Pigeons—In support of the conditional registration of DRC-1339 for use on pigeons in and around structures, Center scientists conducted definitive laboratory studies to determine which concentration(s) on whole corn (0.25 percent and 0.37 percent) and bait dilution ratio(s) (undiluted or diluted at 1:5) produced the greatest mortality. DRC-1339-treated corn baits diluted 1:5 with untreated corn and formulated with alcolec-s, cornstarch, or corn oil at either concentration produced mortality rates below 3 percent. Undiluted DRC-1339-treated corn baits at 0.25-percent and 0.37-percent concentrations and formulated with alcolec-s produced 20-percent and 5-percent mortality, respectively. The same DRC-1339-treated corn baits formulated with cornstarch produced 20- and 68-percent mortality, respectively. Undiluted DRC-1339 formulated with cornstarch on whole corn was selected for further evaluations in field studies to provide efficacy data to satisfy data requirements of the conditional registration.

Compound DRC-1339 98 Percent Concentrate—Livestock Depredations Approved—The registration of DRC-1339 for use in livestock depredation situations was approved by EPA on May 11, 1993, and will allow APHIS to reduce the number of outstanding Section 24(C) State registrations by 12. Not only will this registration reduce the annual cost of maintaining APHIS registrations for ADC State Directors by over $16,000, but it will preserve the flexibility of the 24(C) registrations to meet special local needs in each State. Consolidation of the 24(C) registrations will also reduce data costs when DRC-1339 end-use products are reregistered, beginning in FY 1995.

Chemical Formulations—Formulation of new or modified bait products with APHIS/ADC-registered chemicals involved various activities. These included a laboratory study to examine weathering properties and moisture-proofing of alfalfa pellets via food grade shellac. A data base of “formulation recipes” was set up; this data base allows for the rapid retrieval of precise formulation steps for more than 400 baits and products.

Iophenoxic Acid—DWRC scientists conducted cooperative studies with personnel from the School of Forest Resources, University of Georgia, in biomarker evaluations in white-tailed deer with iophenoxic acid. Deer were given the acid orally at 5 mg per kilogram of body weight. Iodine blood sera samples were assayed before treatment and at 1, 3, 5, 7, 9, and 11 weeks after treatment. At 1 and 3 weeks after dosing, the mean iodine value was significantly higher than before treatment. At 5 to 11 weeks after treatment, the mean iodine value was not significantly different from that of control animals, although 1 deer had a value that was about 7 times higher than that of the controls at 5 weeks after treatment. It is possible that iophenoxic acid could be used for determining the consumption of vaccines or immunocontraception agents by white-tailed deer under field conditions.

Livestock Protection Collar: Large Collar Approved—DWRC researchers found that a new configuration of the LPC is effective in reducing predation on large sheep and goats. Tests completed at the Logan field station showed that the larger collar resulted in better control of coyotes than the small collar, which was the only registered product. Results of studies on penned animals were submitted to EPA in FY 1992 with a request to allow registration and use of the larger collar because it contains the same amount of Compound 1080. On July 19, 1993, EPA approved use of the larger version, which should give ranchers more flexibility in dealing with predator depredations on sheep and goats.

Development of New Two-Ingredient Gas Cartridge—DWRC and the Pocatello Supply Depot cooperated during FY 1993 to develop and pilot-test a two-active-ingredient formulation for the APHIS rodent gas cartridge. The new gas cartridge reduces by two the number of active ingredients that have to be supported by APHIS through the reregistration process and will save APHIS more than $200,000 in data-development costs. The new cartridge will simplify the manufacturing process for the Depot and will eliminate the handling of two hazardous ingredients. Data supporting the registration of the new cartridge were submitted to EPA in September 1993, and production of the new cartridge should begin in 1994.

Northern Pocket Gophers—DWRC personnel conducted a pilot study to evaluate three bait base materials and a two-choice preference test method for use on northern pocket gophers. This initial study attempted to assess the bait preference of the animals using two standard tastants, quinine and sucrose, in each of the three baits, but the gophers consumed so little wax material that meaningful preference data could not be obtained. The data on the pelleted and granulated sorghum bait base indicated that the gophers neither preferred nor avoided either tastant over the tested ranges, which normally produce strong responses in most rodents. These results support the view that pocket gophers have adapted their feeding preferences to incorporate a variety of flavors from roots, bulbs, and tubers. Extracts from these natural products may prove more effective in altering the taste-preference behavior of gophers and could lead to the development of flavor attractants and increased bait acceptance.

Strychnine Alkaloid—The Strychnine Consortium is a group of registrants (private industry and State and Federal Government agencies) that generate funds to maintain the availability of strychnine alkaloid as a vertebrate pesticide. As part of the Strychnine Settlement Agreement of March 10, 1989, EPA required that avian reproduction studies be performed to maintain the registration of the compound.

Final reports of reproductive studies to assess strychnine alkaloid's effects on bobwhite quail and mallard ducks were submitted to EPA in March 1993. These studies were paid for by the members of the Strychnine Consortium.

Test results indicated that bobwhite quail are resistant to clinical and reproductive effects from acute and subacute intake of strychnine. In addition, although mallard ducks display clinical signs to strychnine at about one-tenth the doses observed for quail, it should be noted that strychnine products are labeled to prevent use near water. It seems improbable that toxic signs and reproductive effects would occur in waterfowl or gallinaceous species under prescribed, field-use guidelines.

Immunocontraception

DWRC scientists conducted studies to develop immunocontraception vaccine technology to address problems caused by damaging species of wildlife. This research emphasized development and efficacy testing of vaccine preparations and/or oral delivery methodology for white-tailed deer, wild rats, and starlings.

White-Tailed Deer—Two studies were conducted in cooperation with Baylor College of Medicine and The Pennsylvania State University. The first study, on vaccine development involving 32 captive white-tailed does, compared the effectiveness of native porcine zona pellucida (PZP) and two recombinant rabbit zona pellucida vaccine preparations (RZP-1 and RZP-2) to obtain basic information for developing a genetically engineered vaccine for white-tailed deer. PZP was more effective in preventing conception than either of the recombinant vaccines. However, PZP caused delayed conception and a higher incidence of repeat breeding, suggesting that a recombinant vaccine not having these characteristics may result in less stress on bucks and does than PZP.

Future vaccine testing will include conjugation of RZP-1 to keyhole limpet hemocyanin, a high molecular weight protein carrier, to enhance its effectiveness as a deer immunocontraceptive agent and evaluation of the efficacy of two additional recombinants. Working under contract to DWRC, Baylor researchers are making progress in identification of deer zona pellucida DNA. That work is key to developing a species-specific vaccine. Also, encouraging progress was made under a cooperative agreement with Penn State researchers in developing a sperm-binding assay that may prove useful in initial screening of candidate zona pellucida epitopes.

The second study was conducted with 10 white-tailed deer to test the feasibility of using a recombinant form of Bacillus Calmette-Guerin (BCG) for oral vaccination. Test results demonstrated that recombinant BCG can be used to deliver a genetically engineered vaccine to deer orally. However, a DNA probe test must be developed to differentiate between bovine tuberculosis and genetically altered BCG before the latter could be used under free-ranging conditions. Further research on live oral-vaccine vectors will be delayed until nonvector approaches are more fully explored.

Contraceptive Drug Delivery Research—DWRC-Monell scientists, in collaboration with specialists at Vassar College and Rutgers University, have developed and field-tested several bait formulations that could be used for delivery of contraceptive drugs and other pharmaceutical products to white-tailed deer. The most promising formulation is an aqueous mixture containing apple juice, apple odor extract, glycerin, and sodium chloride.

Developing a Vaccine for Norway Rats—DWRC researchers conducted a study to determine the potential of two methods of rodent immunocontraception by comparing immune, hormonal, and natality responses of wild Norway rats to two immunocontraceptive vaccines. One method involved synthetic mouse zona pellucida made antigenic by coupling it to keyhole limpet hemocyanin. The second method involved use of gonadotropin-releasing hormone (GnRH) made immunogenic by coupling it to keyhole limpet hemocyanin.

Of the 90 rats involved in the study, 40 were untreated males and females used to breed treated rats in breeding trials. The 50 vaccine-treated rats were subcutaneously injected with three 100-μg doses of each vaccine (10 male and 10 female sham controls, 10 zona pellucida females, 10 GnRH males, 10 GnRH females). Breeding trials were conducted, and antibody titers were measured by electroimmunosorbent assay to monitor vaccine efficacy. Control rats demonstrated 87-percent breeding success, with litter sizes of 4–8 pups. Both vaccines caused significant immune responses. Zona pellucida-immunized females had a reduction in progesterone following vaccination. However, the GnRH vaccine was markedly more effective than the zona pellucida vaccine (100-percent sterility of both sexes *v.* 50-percent sterility of females with zona pellucida). Male GnRH rats were monitored for 12 months to determine the length of antibody-induced infertility. Testosterone was not detectable and the testicles were approximately 90 percent atrophied up to 11 months after vaccination. There were no significant differences in mortality or changes in body weight between groups throughout the study. Also, with the exception of male scrotum regression, there was no change in appearance.

Oral Vaccine Delivery—Because vaccines are protein in nature, they must be protected against breakdown in the gastrointestinal tract to be effective immunogens when orally administered. To explore the feasibility of encapsulating an immunocontraceptive vaccine in liposomes (5-micron phospholipid membranes), DWRC investigators launched a study involving 90 Norway rats (45 of each gender). The experimental hypothesis is that liposomes will act as slow-release antigen subcarriers, targeting the enclosed vaccine to the Peyers patches of the small intestine for release over an extended period. Initial results have demonstrated the uptake of fluorescent liposomes into the Peyers patches and a decrease in testosterone, suggesting that oral immunization using liposomes is feasible.

Between October 1992 and September 1993, DWRC staff responded to wildlife damage problems and related environmental issues by providing technical assistance in the form of 429 person-days to 12 countries, including Argentina, Bangladesh, Canada, Chad, Costa Rica, Egypt, Guam, Italy, Niger, the Philippines, Portugal, and Uruguay. These consultancies came at the request of the headquarters and missions of the U.S. Agency for International Development (AID) and foreign governments to assess vertebrate pest problems; to review, evaluate, and coordinate present and future research programs; and to participate in workshops and conferences. Also, approximately 2,100 documents were provided in response to requests from 64 countries. Funding has been provided by AID and other donor organizations.

Bangladesh

The vertebrate pest control program in Bangladesh was instituted in December 1978. A vertebrate pest section was established within the Entomology Division of the Bangladesh Agricultural Research Institute (BARI) at Joydebpur, 32 km north of Dhaka. The section was assisted in its research, technology development, strategic planning, technology transfer, and training by DWRC through a participating agency service agreement between AID and USDA. From the beginning, AID-funded DWRC activities involved assisting in organizing the vertebrate pest section, purchasing commodities, developing the laboratory, and implementing research activities. A combination laboratory–office building was completed in July 1979; several outdoor animal facilities have since been added.

DWRC placed three successive wildlife biologists onsite between 1978 and 1990 and provided 46 short-term consultants to the section from 1976 until the close of the project in 1993. DWRC also assisted in the procurement of equipment, supplies, and library resources and in conducting chemical analyses, radiotelemetry studies, and training of counterpart scientists.

The ultimate goal of the project was to institutionalize a vertebrate pest-management research capacity in Bangladesh. To this purpose, the project has succeeded: four of the five counterpart scientists presently working with the vertebrate pest section have received advanced degrees from overseas training, and the section has established its reputation within BARI. Between 1978 and 1993, section scientists produced 37 technical reports and 50 published papers of their findings. A training manual geared for agricultural extension personnel will summarize project findings on vertebrate pest management in Bangladesh.

When the project began, little was known as to how the common rodenticides would affect Bangladeshi rodents. Basic toxicological studies were needed for the rodent species—namely, the lesser and greater bandicoot rats, the roof rat, and the short-tailed mole rat. Toxicity testing was completed on three acute rodenticides—zinc phosphide, benzene sulfonic acid hydrazide (DRC-4575), and bromethalin—on both sexes of the lesser bandicoot rat, and on three chronic anticoagulant rodenticides: brodifacoum, coumatetralyl, and diphacinone. Prior to this research, other rodenticides had been used indiscriminately, including the insecticides chlordane and endrin. When DWRC's Bangladesh project finished, zinc phosphide was registered for use in a bait cake, and three anticoagulant rodenticides, coumatetralyl, brodifacoum, and bromadiolone, were registered for rodent control.

During the 15 years under DWRC expertise, BARI's vertebrate pest section conducted field research to identify the main vertebrate pests of rice, wheat, maize, and sugarcane. The section also developed techniques and strategies to reduce vertebrate pest damage in crops both before and after harvest. Furthermore, a countrywide strategy to reduce losses in aman rice has been adopted by the Government of Bangladesh and implemented in a once-a-year campaign. Fully equipped offices, laboratories, and outdoor facilities for holding rodents, jackals, and birds are currently located on the BARI site, along with a specialized library, computers, photocopiers, and data bases for retrieval of scientific references. The research activities and strategies of the vertebrate pest section were reviewed, and a 5-year program was outlined for the operational phase, which began in June 1993 when AID funding ended. The section is now developing practical control techniques and strategies, and staff are working with extension personnel throughout the country to implement these strategies.

Several DWRC and cooperating scientists traveled to Bangladesh between October 1992 and June 1993 to review current bird research and help plan future studies, assess technical aspects of the 1992 rodent control campaign, and provide technical assistance for rodent and predator research. DWRC personnel also evaluated the rodenticides available to Bangladeshi farmers and assisted BARI in developing a sampling scheme for monitoring the effectiveness of their national rodent control campaign. DWRC scientists made recommendations for future operational programs to manage rodent pests and helped establish long-term research priorities. The final contributions involved preparing necessary reports that summarize project research, training, constraints, lessons learned, and recommendations for future research, cooperation, and followup evaluations.

Chad

In 1986, several Sahelian nations declared national disasters due to massive outbreaks of rodents. AID was hampered in providing assistance due to a lack of knowledge of the rodent species concerned, their population dynamics, and effective control measures. DWRC provided short-term technical assistance in the form of eight scientist-visits to the Sahel during 1987. The crisis response was inadequate due to poor organization and lack of trained incountry personnel, materials, transportation, and time to implement needed control measures. To ensure the implementation of effective crop protection measures in the future, DWRC initiated research to monitor rodent populations, evaluate control techniques, and train Chadian Government personnel to address future recurring rodent population irruptions like those that took place in 1962, 1977, and 1986–87 in the Sahel.

The Chad Rodent Control Research Project was initiated in 1989 as a cooperative program of DWRC, AID/N'Djamena, and the Chadian Ministry of Agriculture's Crop Protection Service with funding from AID. Since the project's inception, DWRC has provided technical, logistical, and administrative support and assistance in the form of 12 consultancies and a total of over 12 person-months of incountry assistance besides the presence of a resident biologist serving as project leader for 14 months. DWRC made numerous literature searches, procured equipment and supplies, and assisted with the production of four technical reports and a progress report.

Funded research identified six rodent species as important pests of dune-grown millet and winter-grown vegetables. All species responded to the greening and maturation of weeds and grasses during and following the rainy seasons by intense breeding. Population monitoring revealed that rodent population peaks are reached in Chad from October until December, depending upon the length of the breeding season. Populations then decline until July or August, when the next breeding season begins.

Rodent population densities also fluctuated over years; from October 1989 until April 1990, trapping success in both wadis and dunes progressively declined. This trend continued for another 2 years, until the excellent rainfall of July–September 1992, when rodent populations again increased to high levels. Data obtained and techniques used during this project will assist Chadian crop-protection specialists in predicting and controlling periodic rodent outbreaks.

Between October 1992 and September 1993, DWRC scientists traveled to Chad to assist scientists of the Ministry of Agriculture in evaluating rodent monitoring and control techniques, studying rodent reproductive biology, monitoring rodent populations, and preparing final project reports and documents needed to close out this project. During the life of the project, 14 issues of "Rat Facts," a 1-page information sheet in both English and French, were prepared and distributed; 1 progress report, 3 quarterly reports, 4 technical reports, and many consultancy reports were prepared; a final report was issued; and a training manual was completed in both French and English and distributed across West Africa.

DWRC–Russian Collaboration

DWRC-Monell scientists established a cooperative research project with specialists at the A. N. Severtzov Institute of Evolutionary Morphology and Ecology of Animals, Russian Academy of Sciences, Moscow. In collaboration with Professor Valery Ilychev of the Sub-Institute for Applied Ecology, a proposal to fund bird and rodent control research at Moscow dump sites was prepared and submitted to the Institute for Soviet American Relations. The proposal has the support of Moscow prefecture, the Moscow pest control board, and the Russian Green party. If funding is awarded, experiments will begin in 1994.

Niger Consultancy

DWRC wildlife biologist Lynwood Fiedler consulted in Niamey, Niger, in September 1993 for AID. In cooperation with crop protection personnel of the Government of Niger, Fiedler used different monitoring methods to survey rodent activity in two agricultural areas. He also presented a 1-day rodent control workshop in Zinder for 21 agricultural agents from different regions of Niger. French copies of the training manual on rodent research and control developed by the Chad Rodent Control Research Project were given to the participants.

Argentina Sabbatical

International programs section chief Richard Bruggers spent approximately 6 months between November 1992 and May 1993 on sabbatical in Argentina, where he was hosted by the Government of Argentina and its National Institute of Agricultural Technology. While in Argentina, Bruggers began to learn Spanish, identified a number of areas of animal damage research in which DWRC and the National Institute could collaborate, guest-lectured in a wildlife management short course at the University of Cordoba, reviewed the Ph.D. research of Maria Elena Zaccagnini, graduate student at Colorado State University, and conducted research on both the movements of radio-equipped chestnut-capped blackbirds in and around maturing ricefields and the usefulness of leg streamers as a marking technique for blackbirds. During this period, Bruggers also visited Uruguay regarding bird pest research there.

Mexico

Rick Engeman, statistician in the program and research support section at DWRC, has been working with researchers at the National University of Mexico in Mexico City on studies of two genera of pocket gophers. Little scientific documentation is available concerning these animals, which cause extensive agricultural losses in Mexico. Manuscripts describing the reproductive characteristics for the two species have been produced, and studies are being designed for damage assessment in various crops, population indexing methods, and evaluation of damage control methods.

Australia

Engeman has also been working with a senior zoologist from the Lands Protection Branch of the Queensland, Australia, State Government. (The Lands Protection Branch is the Queensland State analog to APHIS' ADC program in the United States.) The focus of this research is on dingo predation of livestock with an initial emphasis on evaluating methods for indexing dingo populations.

As a result of his 1991 sabbatical to Australia, Engeman also is involved in research to resolve other human–wildlife conflicts in Queensland. A study is underway to assess grazing levels of wallabies on the spinifex grass that secures the sand dunes on South Stradebroke Island. This is a large sand island that is integral to the Gold Coast Seaway. Excess grazing on the plants that secure the sand could threaten the island's stability. A manuscript describing grazing levels and how they relate to natural characteristics of the island has been accepted for publication. The scientific and esthetic interest afforded by the wallaby populations on the island dictate that conservation be a key objective to any proposed management strategy. Therefore, further studies are underway to obtain more detail about the grazing situation so that optimal management strategies can be implemented.

International Visitors

DWRC hosted international scientists from Argentina, Australia, Bangladesh, China, Egypt, France, Morocco, and Pakistan for various short visits and long-term sabbaticals during FY 1993.

In 1993, Sayed Ahmed, former scientific officer at the Bangladesh Rice Research Institute, returned to DWRC on a contractual basis to prepare several scientific manuscripts on vertebrate pest problems in Bangladesh and draft a training manual on vertebrate pest management for use there.

Robert Oudinet, director of the Normandy Regional Crop Protection Service of the French Ministry of Agriculture, and Patrice Prevel, representing the Chambre d'Agriculture (farm bureau) from La Manche, Normandy, visited DWRC in March 1993 to learn of developments in bird control techniques, particularly on the use of 3-chloro-*p*-toluidine as a roost toxicant. The visitors were also interested in rodent control and the problems of anticoagulant resistance.

Habibur Rahman, from BARI at Joydebpur, visited DWRC in April 1993 and then spent the month of May at the Ohio field station, where he received training in vertebrate pest control research, particularly for birds. Rahman received training in the capture and handling of birds, experimental design and methodology for testing repellants, use of radiotelemetry and color marking for determining movements of birds, analyses of data, and methods for determining feeding habits of birds.

Abdelkader Zaime of the Hassan II Agronomic and Veterinary Institute in Rabat, Morocco, visited the Center in July 1993 to work with DWRC scientists in developing a cooperative research proposal for predicting and studying rodent population cycles in Morocco.

Mohamed Farag El-Sayed, Physiology Department, Egyptian Plant Protection Research Institute, Geiza, Egypt, visited DWRC in July and August 1993 to become more familiar with ADC research in the United States. Farag was on an 8-month postdoctorate fellowship, sponsored by AID, to Bowling Green State University in Ohio, where he conducted research on methods of detection, mechanisms of anticoagulant resistance, and control of populations of house mice in postharvest situations.

Ethel Rodriguez, head of the department of bird pests in the Plant Protection Division of Uruguay's Ministry of Agriculture in Montevideo, spent 3 months at DWRC during the summer of 1993. Rodriguez is a Ph.D. candidate in the Department of Fishery and Wildlife Biology at Colorado State. While at Denver, she completed the first draft of her research thesis entitled "Strategy Development in the Use of Secondary Repellency for Reducing Eared Dove Damage on Sorghum Crops."

Ejaz Ahmad, a Ph.D. candidate at Colorado State from the Vertebrate Pest Control Project in Pakistan, is conducting his doctoral research in cooperation with the product development section of DWRC's Biotechnology Unit to compare the effectiveness of two oral-delivery vaccine systems—the biodegradable microsphere and the liposome—given to the wild Norway rat. If successful, these carriers will be tested on other species, including deer.

The Center hosted four visiting scientists from Queensland, Australia. Two of these visits were extended sabbaticals. In November 1992, Mike Capra, director of the Centre for Biological Population Management at the Queensland University of Technology (QUT) visited DWRC and presented a seminar entitled "Ciguatera Poisoning Down Under." In January 1993, John Wilson, also from QUT, returned to DWRC, where he had previously spent a sabbatical year, and presented a seminar entitled "The Prediction of Mouse Plagues in Australian Cereal Crops." From June to September 1993, Neil White continued the sabbatical exchange series between the Centre for Biological Population Management at QUT and DWRC that previously had sent John Wilson to Denver and Rick Engeman to QUT in Brisbane. While here, White conducted statistical computer simulations on the properties of plotless density-estimation methods using completely enumerated field populations. Lee Allen of the Queensland Lands Protection Branch spent a sabbatical at DWRC in Denver and at various field stations from July through September 1993. Allen was involved in general information exchange concerning wildlife damage situations with a primary emphasis on the commonalities between alleviating dingo and coyote depredations on livestock.

During November 1992, William Andelt and 11 students from his Managing Human–Wildlife Conflicts class at Colorado State University visited the Center to experience some ongoing research activities. They toured the library, bioelectronics laboratory, and other facilities to observe bird research, immunocontraception studies, and bait formulation.

Joe Brooks, DWRC wildlife biologist, presented a discussion on the biology, distribution, and habits of rodents to the Sertoma Club in Englewood, CO, during October 1992. He visited the Smithsonian Institution's National Museum of Natural History in Washington, DC, during February 1993 to confirm the identity of several principal rodent species in Chad. Brooks returned to the Nation's Capital in April to participate in a panel discussion regarding the feasibility of establishing an international electronic bulletin board for crop protection. This panel was cosponsored by the Consortium for International Crop Protection and USDA's Cooperative State Research Service. (The Consortium is a group of representatives from 13 land-grant universities and USDA devoted to international crop-protection projects.) Brooks also met with AID officials to discuss DWRC research and training activities in the West African countries and AID's new integrated pest management initiative.

Brooks represented USDA on the Consortium's executive board at a meeting in Las Vegas in June 1993. Items on the executive board's agenda included discussion of a proposed global bulletin board on integrated pest management and the direction that the Consortium's member universities are taking in the matter of AID's collaborative research support program proposal on integrated pest management.

Brooks presented a paper on the status of the Eurasian wild boar in Pakistan at the Feral Swine Symposium in March 1993 in Kerrville, TX. Feral swine are found in 19 States in the United States. These animals constitute a valuable huntable resource, but they also pose a tremendous threat because of their impact on the environment and their ability to transmit diseases to domestic livestock.

Brooks consulted in the Pribilof Islands of Alaska at the request of FWS in September 1993 to assess the potential of rat infestations on island environments in the Alaska Maritime National Wildlife Refuge and to recommend measures to prevent such rat infestations reaching the Pribilof Islands. During his consultancy, Brooks reviewed the rodent situation on St. Paul and St. George islands, trained local people on rodent detection, introduction, and prevention, and evaluated procedures and ordinances regarding rodent inspections on ships. A proposal/concept paper is being prepared for followup activities.

Wildlife biologist James Keith attended the first international congress of the Society of Environmental Toxicology and Chemistry in Lisbon, Portugal, during March 1993. He presented findings from African research on the effects of pesticide sprays on quelea birds in Kenya and the nontarget impacts of locust sprays in Senegal and Morocco.

Keith presented a paper entitled "Insecticides: Why Are Animals Killed Only Some of the Time?" at the International Union of Game Biologists' 21st congress in Halifax, Canada, in August 1993.

Lynwood Fiedler traveled to the Philippines to participate on the APHIS panel in the AID-sponsored Asia/Pacific regional agricultural products quality workshop held in Manila in May 1993. He presented a paper on vertebrate pests as constraints to agricultural production and quality in the Asia/Pacific region and exchanged information on specific problems of rodents, birds, and other vertebrate pests affecting a variety of private agribusiness ventures within the region.

In May 1993, Richard Bruggers represented DWRC at the first meeting of the aquatic nuisance species task force's Brown Tree Snake Control Committee in Senator Inouye's conference room in Honolulu, HI. The purpose of this committee was to develop a comprehensive program that includes elements of education, prevention, and research for solving the brown tree snake problem on Guam. The committee was composed of representatives of the Department of Defense/Armed Forces Pest Management Board, USDI/FWS, and National Wildlife Health Center, USDA/APHIS ADC and Program Planning and Development, and representatives of Hawaii, Guam, and Saipan.

Bruggers and Gary Witmer attended the First International Wildlife Management Congress in San Jose, Costa Rica, in September 1993. This meeting was primarily sponsored and organized by The Wildlife Society. About 700 individuals from 70 countries attended. Bruggers was coauthor of a poster session on blackbird problems in rice in Argentina, and Dr. Witmer was coauthor of a poster session on international rodent problems and presented a paper on predator control and conservation in Costa Rica. The theme of the meeting, "Integrating People and Wildlife for a Sustainable Future," emphasized development of wildlife conservation strategies that attend to the needs of people and conservation strategies that focus on biological diversity, with the hope of developing an international vision for management of wildlife resources for the 21st century.

Bob Phillips, research biologist in DWRC's mammal control research section, presented programs on eagle ecology and management to three different groups in Boulder, CO, during FY 1993. He also spoke to school children at two elementary schools about eagle ecology.

Phillips and Rick Engeman attended the International Standards Organization's Working Group 3 meeting in Vancouver in April 1993. This group is charged with developing humane standards for various types of mammal restraint devices. The meeting was attended by representatives from the United States, Canada, the United Kingdom, Sweden, and New Zealand. Engeman gave a presentation on the mathematical/statistical properties of injury scoring systems for evaluation of injuries to trapped animals and also offered alternative methods for quantifying injuries.

Following the working group meeting, the U.S. Technical Advisory Group met to discuss formal comment on the draft trap standard. That group included representatives from APHIS' ADC program, universities, State wildlife agencies, animal welfare interests, trap manufacturers, and national and State trapping organizations. Proposed trap standards are scheduled for presentation to the international community in 1994.

On behalf of the DWRC Director, Engeman conducted a funding review for the Centre for Biological Population Management at the QUT in Brisbane, Australia. To maintain continued funding, the Centre is required periodically to provide a review of its operations. This review requires extensive comments from external referees. The nature of DWRC's work is similar to that of the Centre, and Engeman is very familiar with the Center's work from his 1991 sabbatical at QUT.

Bruce Kimball and Carol Furcolow, of DWRC's analytical chemistry section, were invited by EPA to be instructors at a pesticide formulation analysis workshop. Furcolow provided instruction on diphacinone bait analysis to chemists from laboratories around the country. Kimball taught a segment on Compound 1080 analysis and gave a presentation entitled "Analytical Method Development and Validation at the Denver Wildlife Research Center."

Paige Groninger, computer specialist in the program and research support section, provided consultations on statistical analysis system programming to people in various programs in APHIS.

Members of DWRC's Florida field station staff participated in field day activities for rice growers in Vermillion Parish, LA. They discussed with the growers research that is being conducted to develop new tools for protecting rice from damage by blackbirds.

Mike Avery, the project leader of the Florida field station, presented a seminar at the University of Florida entitled "Animal Welfare Concerns in Wildlife Research." This presentation was part of an animal rights/animal welfare seminar series sponsored by the University Veterinarian's office. Avery's presentation on the use of wild birds as experimental subjects focused on research activities and animal care procedures at the Florida field station.

As part of an ongoing cooperative research and training relationship between the station and the University of Florida, personnel at the field station assisted in teaching the Zoology Department's advanced ornithology class. At the field station, students received an introduction to DWRC's Florida research activities and then participated in practical exercises on the capture and safe handling of wild birds.

The board of directors of Catfish Farmers of Mississippi met December 1–2, 1992, at Mississippi State University to review University research studies involving the catfish industry. As part of this 2-day program, Don Mott, the project leader of the DWRC Mississippi field station, gave a presentation summarizing ongoing and completed research on double-crested cormorant predation on catfish.

On April 9, 1993, Mott attended the Catfish Farmers of Mississippi's annual field day near Belzoni, MS, and presented a poster display highlighting DWRC research accomplishments in the area of bird depredations on catfish. On July 20, 1993, he attended the American Fisheries Society's fish health section meeting in Denver, CO, and presented a paper entitled "Research on Avian Depredations at Mississippi Aquaculture Facilities." The increase in bird problems in aquaculture nationwide has stimulated interest on new developments in control strategies.

Mississippi research station staff attended and participated in the annual Colonial Waterbird Society meeting held in Oxford, MS, (University of Mississippi) October 14–18, 1992. A cormorant symposium held in conjunction with this meeting gave station scientists the opportunity to present results of research on cormorant bioenergetic modeling, foraging rates, telemetry-obtained activity budgets, and control strategies. This meeting, which was strongly supported by the ADC program, provided a unique opportunity to exchange information and philosophies among aquaculturists, personnel from FWS and the Canadian Wildlife Service, and members of various ornithological societies and universities. International participants included travelers from Canada, France, Italy, Japan, Portugal, and the United Kingdom.

On January 5–6, 1993, the Mississippi research station staff attended the National Aquaculture Association Expo IV in New Orleans, LA, and gave presentations on results of station research. As part of Expo IV, a special symposium sponsored by the National Aquaculture Association and the National Audubon Society focused on the relationships between fish-eating birds and the aquaculture industry.

On September 2, 1993, the Mississippi research station in cooperation with Mississippi ADC hosted a coordination meeting on the control of fish-eating bird damage at Stoneville, MS. This meeting was held to foster a better understanding of the nature and solutions to problems caused by fish-eating birds. Participants had an opportunity to listen to representatives from Federal and State agencies and catfish-industry personnel address their needs and concerns. Current ADC research and operational programs were discussed, as were proposed studies with double-crested cormorants and white pelicans. This meeting, intended as an annual event, was well received by those in attendance.

DWRC-Monell scientists hold senior staff appointments at the Monell Chemical Senses Center and are key faculty in the graduate program in conservation biology in the Department of Biology at The University of Pennsylvania. On average, DWRC personnel supervise the preparation of 2–4 graduate theses annually and teach 2–3 undergraduate/graduate courses. In addition, DWRC-Monell scientists have academic appointments in the Department of Animal Science at Rutgers University.

Information Transfer/Library

The DWRC library provided extensive reference and information services to ADC personnel, cooperators, and other Federal agencies. Library staff worked with DWRC's pesticide registration group to provide information on deer mice and the hantavirus to aid staff in their work with the Centers for Disease Control and Prevention. Information was also provided to FWS personnel on wildlife species and pesticides found at the Rocky Mountain Arsenal superfund cleanup site. Resources to complete components of environmental assessments and the ADC environmental impact statement were provided to ADC operations personnel. Library staff worked with researchers to provide information for reviews on small mammals in rangelands, gull problems at airports, and pesticide residues in wildlife. Other information requests included subjects such as FLIR, feral cats, black bear damage, olfactory repellants, biological control of vertebrate pests, bird-borne diseases, DNA fingerprinting, elephant damage, lead-shot and raptors, deer and antelope mortality, and food habits of various animals.

Library staff upgraded several products and introduced new ones, including an electronically searchable copy of DUCKDATA. This reference source was compiled by FWS staffers and contains more than 10,000 citations pertaining to North American or holarctic waterfowl. Abstracts of all Wildlife Society journal articles (and Wildlife Monographs) were purchased from Absearch and are now available on disk. Author, title, and keyword searching is available. The Wildlife Worldwide CD-ROM data base has added material from the Fish and Wildlife Reference Service files. New inhouse computerized data bases on Pro-Cite have been added to the library, including Beavers, Strychnine, updated and expanded Zinc Phosphide, Markers, and Public Attitudes Toward Wildlife Management.

The library responded to 3,350 requests for reprints of articles by DWRC authors. More than 650 requests for books and photocopies were received electronically via the On Line Computer Library Center, Inc., and DWRC interlibrary loan staff requested more than 2,000 items from other institutions in response to requests from patrons.

Behind the scenes, the library has initiated a bar-coding project and collection inventory to upgrade circulation services. Brochures providing information on the library and on the predator data base have been published. A draft library marketing plan has been written, and a library newsletter for ADC staff has been published. Newer, faster methods of obtaining offsite documents were evaluated. The library now has access to the Internet information highway and all its resources. Access to the Internet enables staff to electronically search library catalogs throughout the world, communicate and share ideas with colleagues at remote institutions, request help in answering difficult reference questions, and access government and privately owned data bases containing legal, biological, environmental, business, and other information resources.

Archives

The archives unit participated in the inspection of DWRC's animal care facilities and records by APHIS' Regulatory Enforcement and Animal Care unit. The Animal Care and Use Committee records were added to the archives, and an archives staff member participated in an Animal Care and Use Committee inspection at the Sandusky field station. During FY 1993, 32 studies were accessioned, including 23 Good Laboratory Practices studies, 4 pilot studies, and 5 other studies. Four groups of tissue samples were also archived as well as nine groups of miscellaneous research materials. Various historic ADC State reports were collected and cataloged. In FY 1993, the Archives staff assumed responsibility for responding to all Freedom of Information Act requests directed to DWRC. As part of a longrange goal to tranfer technology and increase communication with staff and the public, a brochure publicizing DWRC's archive services for DWRC staff was produced.

Analytical Methods Development

Nine original analytical methods were developed and validated in support of the ADC program's pesticide registration effort. Most pesticide registration studies require chemical analysis to verify the active ingredient concentration. A more difficult requirement is the development of methods for detecting residues—methods that are fundamental to assessing secondary hazards of pesticides. Development of these methods was vital to successfully completing a gas cartridge burn-time study, DRC-1339 efficacy study, DRC-1339 secondary hazard study, and various zinc phosphide, strychnine, and α-chloralose studies. For many of these studies, no analytical methodology was previously available.

Animal Care

Transporting wild animals can be a challenge. Commonly, there is little knowledge available on the proper procedures for shipping the species DWRC researchers use. Many of the problems involved in the shipment of pocket gophers have been eliminated by the development of new transport containers by animal care staff at the Center. The new containers provide durability and ease of access for staffers, as well as protection from injury and environmental extremes for the animals. The new cages worked very well during use to transport pocket gophers.

All animal care staff have become proficient in data-base management. As a result, staff members can quickly locate animal records to determine the current status of an animal or a group of animals at DWRC.

Quality Assurance

Steve Greiner, DWRC's chemical hygiene officer, has developed and implemented the DWRC chemical management plan. The plan consists of standard operating procedures that govern the ordering, receipt, dispensing, storage, use, tracking, accountability, and disposal of chemicals. The plan was developed to enhance Good Laboratory Practice procedures, minimize hazardous waste generation, and establish a safer and healthier work environment for DWRC employees. Each DWRC field station will develop specific procedures for complying with the chemical management plan in their own unique situations.

Statistics

Sampling Methods for Damage Assessment—In his 1991 sabbatical to QUT in Brisbane, Australia, Rick Engeman conducted extensive computer simulations on a wide variety of plotless sampling methods. The purpose of this research was to determine which methods offer less labor-intensive means of producing similar estimation quality in comparison to the traditional quadrat estimators. These simulations allowed a theoretical statistical comparison of the methods for a variety of population distributions. However, theoretical results need to be verified in the field. To this end, DWRC acquired data on a diverse group of field populations from around the world. These included distributions of animal damage points in various crops, distributions of bird nests, distributions of plant species, and distributions of pocket-gopher burrow systems. Altogether, more than 20 such field populations were completely enumerated for further testing of the sampling methods. These comparisons were accomplished through a sabbatical visit to DWRC by Neil White of QUT, whose visit was designed as a followup to Engeman's work in Australia.

The tests on completely enumerated populations verified that high-quality estimation can be achieved with several sampling methods that are simple in concept and much less labor intensive than quadrat sampling. The most practical methods to implement in a field situation appear to be the ordered distance method (where the area to locate the three nearest members of the population to a random sampling point is measured), the variable area transect (where a fixed-width strip transect is followed from each random point until three population members are encountered), and an extension to the method by Kendall and Moran (where the area measured is from the random sample point to the nearest population member, from that member to its nearest neighbor, and from that individual to its nearest neighbor).

Injury Assessment—Injury scoring methods have often been used to quantify the extent of injury incurred by a trapped animal. Injury scores are numerical point tallies of the injuries of a captured animal based on predetermined values assigned to the possible types of injuries. Statisticians at DWRC investigated the mathematical/statistical properties of scoring systems and analyzed injury-score data to demonstrate the theoretical and practical pitfalls associated with using scoring systems to evaluate and compare injuries incurred by animals in various traps. Injury scores were shown not to possess the mathematical properties necessary to be an accurate numerical description of the injuries accumulated by an animal caught in a restraining device. Similarly, injury scores violate the assumptions upon which all but the simplest statistical data-analysis methods are based. Practical alternatives for quantifying injuries also were suggested in a manuscript on the topic.

Research and Support Staff by Area of Expertise

Birds

Avery, Michael L., Supervisory Wildlife Biologist (Research)—Development of nonlethal bird-management methods; investigations of avian feeding behavior, exotic species, and international crop damage problems.

Clark, Larry, Biologist (Research)—Discovery and development of vertebrate repellants and attractants using molecular modeling techniques for use in crop protection, bait formulations, and wildlife conservation.

Cummings, John L., Wildlife Biologist (Research)—Development of repellants for agricultural crops and grass to reduce damage caused by waterfowl, specifically Canada geese.

Dolbeer, Richard A., Wildlife Biologist (Research)—Population studies of vertebrate pest species, development of cultural techniques for reducing bird damage to agricultural crops, and studies of safety hazards caused by wildlife at airports.

Dwyer, Chris P., Wildlife Biologist (Research)—Bird–aircraft strike research and gull biology.

Glahn, James F., Wildlife Biologist (Research)—Problem definition and control-methods development studies of winter-roosting blackbirds and starlings and fish-eating birds in commercial aquaculture.

King, David T., Wildlife Biologist—Radio-telemetry studies with double-crested cormorants and problem-definition studies of bird damage.

Mason, J. Russell, Research Psychologist—Development of vertebrate class-specific chemical repellants and biologically based chemical attractants for birds and rodents.

Mott, Donald F., Supervisory Wildlife Biologist—Problem-definition and control-methods development studies of winter-roosting blackbirds and starlings and fish-eating birds in commercial aquaculture.

Pochop, Patricia A., Wildlife Biologist—Bird damage research and control.

Stickley, Allen R., Wildlife Biologist (Research)—Problem-definition and control-methods development studies of winter-roosting blackbirds and starlings and fish-eating birds in commercial aquaculture; also histoplasmosis problems in regard to bird roosts.

Wager-Page, Shirley A., Toxicologist (Research)—Avian and rodent nonlethal repellants, chemosensory irritants, and markers of neuronal activation (c-fos).

Woronecki, Paul P., Wildlife Biologist (Research)—Development of methods for capturing nuisance birds, evaluation of nontarget wildlife hazards related to use of avicides, and evaluation of various techniques for repelling birds.

International Programs

Brooks, Joe E., Wildlife Biologist (Research)—Vertebrate pest management related to agricultural crops and human health, particularly in tropical and subtropical countries.

Bruggers, Richard L., Wildlife Biologist (Research)—Vertebrate pest management related to agricultural crops in tropical and subtropical countries.

Keith, James O., Wildlife Biologist (retired)—Impacts of pesticides on wildlife.

Mammals

Burns, Richard J., Wildlife Biologist (Research)—Application of behavioral patterns and principles to develop new or improved depredation-control devices and tools.

Campbell, Dan L., Wildlife Biologist (Research)—Silvicultural modifications; aversive conditioning, repellants and barriers for forest and agricultural animals; toxicant evaluations.

Fiedler, Lynwood A., Wildlife Biologist (Research)—Rodent pest management in tropical agricultural crops.

Gruver, Kenneth S., Wildlife Biologist—Predator biology and control.

Jaeger, Michael M., Zoologist (Research)—Studies of predator biology, behavior, and control.

Knowlton, Frederick F., Wildlife Biologist (Research)—Incorporation of ecologic, demographic, and behavioral information into depredation-control programs to make them more effective, efficient, and socially acceptable.

Matschke, George H., Wildlife Biologist (Research)—Laboratory and field evaluations of rodenticides and chemosterilants.

Nolte, Dale L., Research Ecologist—Chemoecology, plant–animal interactions, and behavioral and habitat modification.

Pan, Huo-Ping, Research Chemist—Development of safe predator-control agents and methodology by creative application of biochemistry.

Phillips, Robert L., Wildlife Biologist (Research)—Research to improve tools used in controlling coyote depredation.

Tobin, Mark E., Wildlife Biologist—Wildlife ecology especially as it relates to the impact and control of vertebrate agricultural pests.

Windberg, Lamar, Wildlife Biologist (Research)—Predator population dynamics and identification of depredation control procedures that are selective for individuals causing problems.

Witmer, Gary W., Wildlife Biologist (Research)—Studies of predator biology, behavior, and control.

Zemlicka, Doris E., Wildlife Biologist—Coyote behavior studies and development of more acceptable depredation-control practices.

Chemistry/Registration of Pesticides

Elias, Donald J., Wildlife Biologist (Research)—International vertebrate pests, primarily in Latin America; economic impact of vertebrate pests.

Garrison, Melvyn V., Research Physiologist—Bait formulation, toxicity testing, and animal nutrition.

Goldade, David A., Chemist—Technical formulation assays, and residue determinations for pesticides.

Goodall, Margaret J., Chemist—Scheduling, oversight, and qualitative and quantitative assessments of pesticides and other chemicals used in the Center's research.

Hurlbut, Daniel B., Chemist—Chemical research and development of analytical methods to support environmental-fate studies for agricultural chemicals.

Johns, Brad E., Research Physiologist—Wildlife physiology as related to toxicants, marking agents, and reproductive inhibitors.

Kelly, Kevin L., Research Chemist—Investigation of applicability of supercritical fluid technology to analytical research.

Kimball, Bruce A., Research Chemist—Analytical chemistry support to DWRC scientists conducting exploratory research.

Knittle, C. Edward, Wildlife Biologist (Research)—Telemetry and related behavioral activities of avian species.

Miller, Lowell A., Research Physiologist (Immunology)—Immunocontraception, vaccine delivery systems, and immunology laboratory science.

Okuno, Wally, Research Chemist—Conduct of chemical research and development of analytical methods relating to animal damage control.

Primus, Thomas M., Research Chemist—Development of methods for the analysis of agricultural chemicals in baits, formulations, and other matrices.

Ramey, Craig A., Wildlife Biologist (Research)—Chemical registration; telemetry and population biology of vertebrates.

Savarie, Peter J., Pharmacologist (Toxicology)—Predacides and rodenticides.

Schafer, Edward W., Jr., Supervisory Research Chemist—Avian toxicology and chemical registrations.

Schulz, Gaylord A., Wildlife Biologist—Pesticide registration research.

Shumake, Stephen A., Research Psychologist—Sensory characteristics, conditioning, learning effects, and natural behavior of vertebrates.

Starr, Robert I., Research Chemist—Studies in soil chemistry, the environmental fate of pesticides, plant physiology, biochemistry, and pesticide methods development.

Sterner, Ray T., Research Psychologist—Vertebrate feeding behavior and aversion or bait shyness responses.

Thompson, R. Daniel, Research Physiologist—Animal physiology and control-methods development pertaining to avian pest species, wild rodents, and vampire bats; environmental physiology of dairy cattle.

Volz, Stephanie A., Chemist—Analytical chemistry services and research.

Information Transfer

Connolly, Guy, Wildlife Biologist (Liaison)—All aspects of wildlife damage management, as well as coyote depredation control and control methods such as the livestock protection collar and M-44 sodium cyanide ejector.

Dwyer, Diana L., Supervisory Technical Information Specialist—Information and technology transfer of vertebrate pest-control research and the development of information data bases.

Paulik, Laurie A., Librarian (Biological Sciences)—Development and maintenance of library reference, technical services, and information access capabilities to respond to user requests for online searches, reprints, reports, and other materials.

Smillie, Sella A., Records Manager (Archives)—Development of DWRC's Archives for the storage and protection of scientific studies and other research; management of current DWRC records.

Program Support

Dale, Albert F., Supervisory Veterinary Medical Officer—Veterinary medicine and care of captive wild animals.

Dusenberry, William E., Supervisory Statistician—Statistical consultation, experimental design, automated data processing planning.

Engeman, Richard M., Statistician (Biology)—Sampling and experimental design development for animal damage studies.

Greiner, Steven J., Safety and Occupational Health Specialist—Employee safety and health, chemical management, and hazardous waste disposal.

Groninger, N. Paige, Computer Specialist—Data-base and systems design, computer programming, and microcomputer hardware and software setup.

Kolz, A. Lawrence, Supervisory Electronics Engineer—Development of electronic instrumentation for applications in wildlife control methods, population monitoring, and behavioral studies.

Krupa, Heather W., Statistician—Experimental design development and review, data analysis, and statistical computing.

Mitchell, G. Clay, Quality Assurance Officer—Research study audits and Good Laboratory Practice Standards compliance.

(Boldface type identifies DWRC personnel.)

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